UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	865.4339 DI
First Named Inventor or Application Identifier	
	HIROKI NAKAYAMA
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. [X] Fee Transmittal Form *(Submit an original, and a duplicate for fee processing)*
2. [X] Specification — *Total Pages* 41
3. [X] Drawing(s) *(35 USC 113)* — *Total Sheets* 15
4. [X] Oath or Declaration — *Total Pages* 1
   - a. [ ] Newly executed (original or copy)
   - b. [ ] Unexecuted for information purposes
   - c. [X] Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 17 completed)* ***[Note Box 5 below]***
     - i. [ ] DELETION OF INVENTOR(S) Signed Statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1 33(b).
5. [X] Incorporation By Reference *(useable if Box 4c is checked)* The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4c, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. [ ] Microfiche Computer Program *(Appendix)*
7. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   - a. [ ] Computer Readable Copy
   - b. [ ] Paper Copy (identical to computer copy)
   - c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. [ ] Assignment Papers (cover sheet & document(s))
9. [ ] 37 CFR 3.73(b) Statement *(when there is an assignee)* [X] Power of Attorney
10. [ ] English Translation Document *(if applicable)*
11. [X] Information Disclosure Statement (IDS)/PTO-1449 [X] Copies of IDS Citations
12. [X] Preliminary Amendment
13. [X] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
14. [ ] Small Entity Statement(s) [ ] Statement filed in prior application Status still proper and desired
15. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
16. [X] Other: Request for Approval to Amend the Drawings with 2 sheets of drawings; Letter Transmitting Corrected Formal Drawings with 2 sheets of drawings

17. If a CONTINUING APPLICATION, *check appropriate box and supply the requisite information:*
[ ] Continuation [X] Divisional [ ] Continuation-in-part (CIP) of prior application No. 09/248,979 filed February 12, 1999.

18. CORRESPONDENCE ADDRESS

[X] Customer Number or Bar Code Label 05514 (Insert Customer No. or Attach bar code label here) or [ ] Correspondence address below

NAME					
Address					
City		State		Zip Code	
Country		Telephone		Fax	

Jc685 U.S. PTO 09/12/00

Jc903 U.S. PTO 09/660502 09/12/00

CLAIMS	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
	TOTAL CLAIMS (37 CFR 1.16(c))	29-20 =	9	X $ 18.00 =	$ 162.00
	INDEPENDENT CLAIMS (37 CFR 1.16(b))	2-3 =	0	X $ 78.00 =	$ 0.00
	MULTIPLE DEPENDENT CLAIMS (if applicable) (37 CFR 1.16(d))			$260.00 =	$ 260.00
				BASIC FEE (37 CFR 1.16(a))	$ 690.00
			Total of above Calculations =		$1,112.00
	Reduction by 50% for filing by small entity (Note 37 CFR 1.9, 1.27, 1.28).				
				TOTAL =	$1,112.00

19. Small entity status
    - a. ☐ A Small entity statement is enclosed
    - b. ☐ A small entity statement was filed in the prior nonprovisional application and such status is still proper and desired.
    - c. ☐ Is no longer claimed.

20. ☒ A check in the amount of $ 1,112.00 to cover the filing fee is enclosed.

21. ☐ A check in the amount of $ __________ to cover the recordal fee is enclosed.

22. The Commissioner is hereby authorized to credit overpayments or charge the following fees to Deposit Account No. 06-1205:
    - a. ☒ Fees required under 37 CFR 1.16.
    - b. ☒ Fees required under 37 CFR 1.17.
    - c. ☐ Fees required under 37 CFR 1.18.

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED	
NAME	Gary M. Jacobs - Registration No. 28,861
SIGNATURE	Gary Jacobs
DATE	September 12, 2000

GMJ\tnt

865.4339 DI

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

HIROKI NAKAYAMA

Appln. No.: Unassigned (Divisional of Appln. No. 09/248,979 filed February 12, 1999)

Filed: September 12, 2000

For: ZOOM LENS AND PHOTOGRAPHING APPARATUS HAVING THE SAME

Examiner: M. Lucas

Group Art Unit: 2873

September 12, 2000

Assistant Commissioner for Patents
BOX PATENT APPLICATION
Washington, DC 20231

PRELIMINARY AMENDMENT

Sir:

Prior to examination on the merits, please amend the above-identified application as follows:

IN THE SPECIFICATION:

Please amend the specification as follows:

Page 2,

Before Line 1, insert --This application is a division of Application No. 09/248,979 filed February 12, 1999.--

Line 25, change “5,283,639” to --5,283,693--.

Page 3,

Line 18, delete “has” and after “only” insert --has--.

Line 19, after “increase” insert --,--.

Line 25, after “is’ insert --a--.

Page 4,

Line 1, after “to” insert --a--.

Line 8, after ‘the” insert --manufacturing-- and delete “on”.

Line 9, delete “manufacturing”.

Line 11, delete “in finish”.

Line 12, after “another” insert --patent,--.

Line 19, change “failed to correct” to --not corrected--.

Line 21, change “make with” to --lessen the-- and change “by using” to --with which--.

Line 22, after “techniques” insert --are used--.

Line 24, delete “the” (first occurrence).

Line 26, change “short” to --small--.

Page 5,

Line 3, change "compact form" to --compactness of the camera--.

Line 6, after "is" insert --designed-- and change "negative" to --negative- --.

Line 7, change "lead type in the" to --lead-type of--.

Line 8, change "form and" to --form,-- and change "construction and" to --construction, and the--.

Line 20, after "wherein" insert --a--.

Line 21, change "a" to --the--.

Page 6,

Line 3, change "in" to --at--.

Line 6, change "in" to --at--.

Line 9, change "in" to --at--.

Line 12, change "in" to --at--.

Line 15, change "in" to --at--.

Line 18, change "in" to --at--.

Line 21, change "in" to --at--.

Line 24, change "in" to --at--.

Line 27, change "in" to --at--.

Page 7,

Line 2, change "in" to --at--.

Line 5, change "in" to --at--.

Line 8, change "in" to --at--.

Page 7,

Line 11, change "in" to --at--.

Line 14, change "in" to --at--.

Line 17, change "in" to --at--.

Line 20, change "in" to --at--.

Line 23, change "in" to --at--.

Line 26, change "in" to --at--.

Page 8,

Line 4, change "in" to --at--.

Line 7, change "in" to --at--.

Line 10, change "in" to --at--.

Line 13, change "in" to --at--.

Line 16, change "in" to --at--.

Line 19, change "in" to --at--.

Line 22, change "in" to --at--.

Line 25, change "in" to --at--.

Page 9,

Line 13, after "element" insert --,-- and change "as CCD" to --as a CCD,--.

Line 14, after "block" insert --,--.

Line 21, after "with" insert --a--.

Page 10,

Line 19, after "with" insert --the--.

Line 20, after "with" insert --the--.

Page 10,

Line 24, change “too much” to --much too--.

Line 25, after “strong” insert --,--.

Page 11,

Line 3, change “take equal shares” to --contribute equally to--.

Line 4, delete “of” and delete “to each other”.

Line 17, delete “made”.

Line 18, after “with” insert --the--.

Page 13,

Line 23, delete “the”.

Page 16,

Line 10, delete “it”.

Page 18,

Line 17, after “unit” insert --,--.

Line 19, delete “it”.

Page 19,

Line 1, change “little” to --small--.

Line 17, after “unit” insert --,--.

Line 19, delete “it”.

Page 20,

Line 24, delete "made".

Page 21,

Line 26, delete "made".

Page 23,

Line 1, delete "made".

Line 14, change "an" to --the--.

IN THE CLAIMS:

Please add Claims 13 through 19 as follows:

--13. A zoom lens comprising, in order from an object side to an image side,

a first lens unit of negative refractive power, located closer to the object side than any lens units of the zoom lens,

an aperture stop,

a second lens unit of positive refractive power,

wherein the separation between the first lens unit and the second lens unit is varied during zooming, and the following condition is satisfied:

$$3 \leq NL1 \leq 4$$

$$NL2 \leq NL1$$

wherein NL1 and NL2 are the numbers of lens elements comprising the first lens unit and the second lens unit respectively.

14. A zoom lens according to Claim 13, wherein the aperture stop moves during the zooming.

15. A zoom lens according to Claim 14, wherein the aperture stop moves unitedly with the second lens unit.

16. A zoom lens according to Claim 13, wherein the first lens unit has two negative lens elements, one of which, having a smaller diameter, has an aspherical surface.

17. A zoom lens according to Claim 13, wherein the second lens unit consists of two lens elements, and has an aspherical surface both on a lens surface closest to the object side and a lens surface closest to the image side.

18. A zoom lens according to Claim 13, wherein the second lens unit consists of one lens element and has an aspherical surface both on a lens surface closest to the object side and a lens surface closest to the image side.

19. A zoom lens according to Claim 13, wherein the second lens unit consists of three lens elements, and has an

aspherical surface on a lens surface closest to the object side.--.

REMARKS

This is a divisional application of Application No. 09/248,979 filed February 12, 1999 (the "'979 Application").

Claims 1 through 19 are pending, with Claims 1 and 13 being independent. Claims 13 through 19 have been added.

The specification has been amended to include changes made in the '979 Application.

Applicant claims under 35 U.S.C. § 119 based upon Japanese Priority Application Nos. 10-054434 filed February 19, 1998, and 11-011288 filed January 20, 1999, and respectfully request acknowledgment of this claim and of receipt of the certified copies of the priority documents, which were filed May 26, 2000, in the '979 Application.

Applicant submits that this application is in condition for allowance, and a Notice of Allowance is respectfully requested.

Applicant's undersigned attorney may be reached in our Washington, D.C. office by telephone at (202) 530-1010. All correspondence should continue to be directed to our below-listed address.

Respectfully submitted,

Attorney for Applicant

Registration No. 28,861

FITZPATRICK, CELLA, HARPER & SCINTO
30 Rockefeller Plaza
New York, New York 10112-3801
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GMJ\tnt

865.4339 DI

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	
	:	Examiner: M. Lucas
HIROKI NAKAYAMA	)	
	:	Group Art Unit: 2873
Appln. No.: Unassigned (Divisional of Appln. No. 09/248,979 filed February 12, 1999)	) :) :) :	
	)	
Filed: September 12, 2000	:	
	)	
For: ZOOM LENS AND PHOTOGRAPHING APPARATUS HAVING THE SAME	:) :	September 12, 2000

Assistant Commissioner for Patents
BOX PATENT APPLICATION
Washington, DC 20231

REQUEST FOR APPROVAL TO AMEND THE DRAWINGS

Sir:

Enclosed in accordance with U.S. Patent and Trademark Office practice are proposed drawing changes, in red ink, wherein Figs. 2 and 3 have been amended to replace the grouping lines to show movement together of the second lens unit and the stop SP.

These amendments were approved in Application No. 09/248,979 filed February 12, 1999, the parent of the above-referenced application.

Approval hereof is earnestly solicited.

Applicant's undersigned attorney may be reached in our Washington, D.C. office by telephone at (202) 530-1010. All correspondence should continue to be directed to our below-listed address.

Respectfully submitted,

[signature]

Attorney for Applicant

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FIG. 1

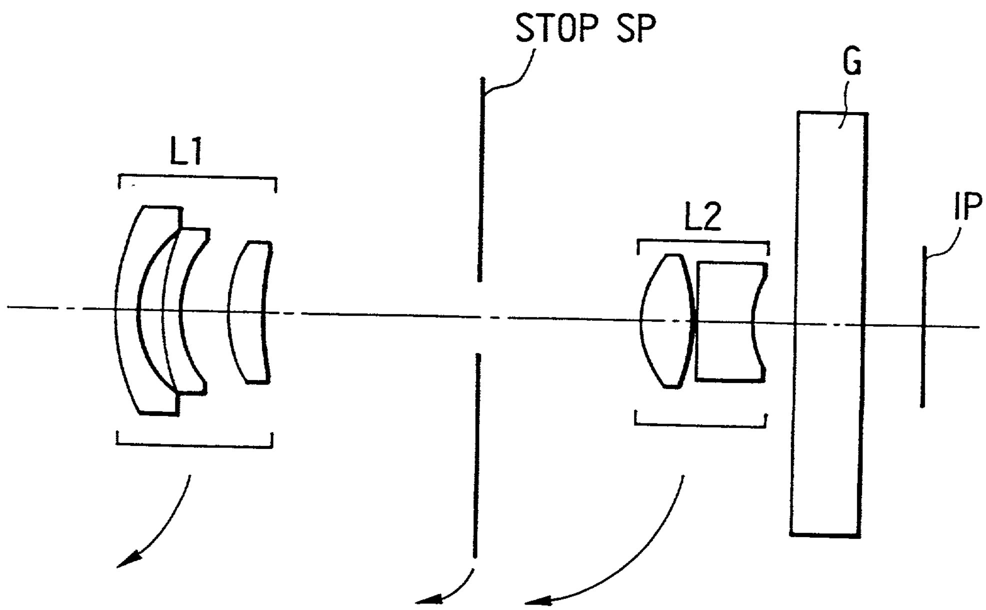


FIG. 2

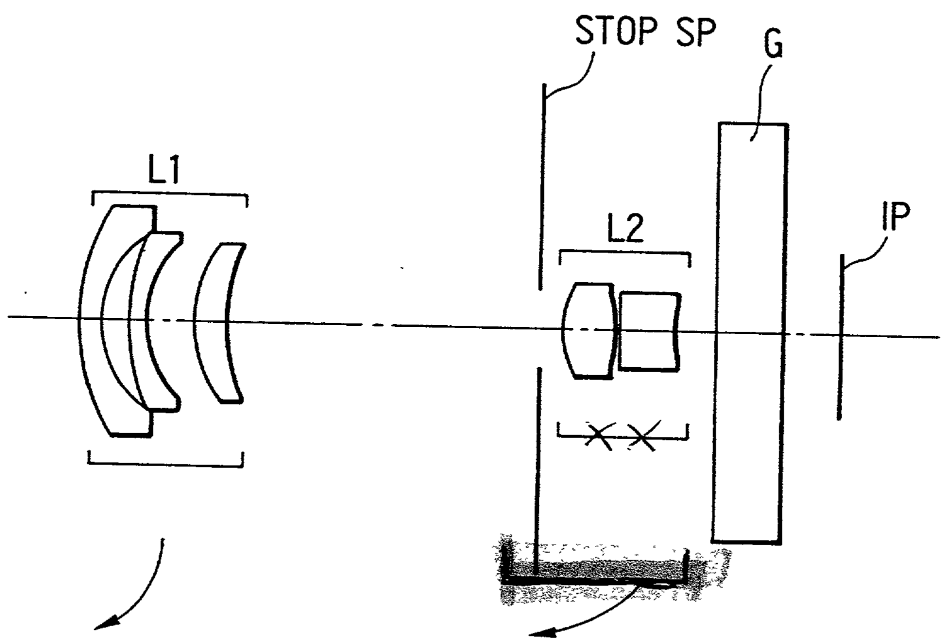


FIG. 3

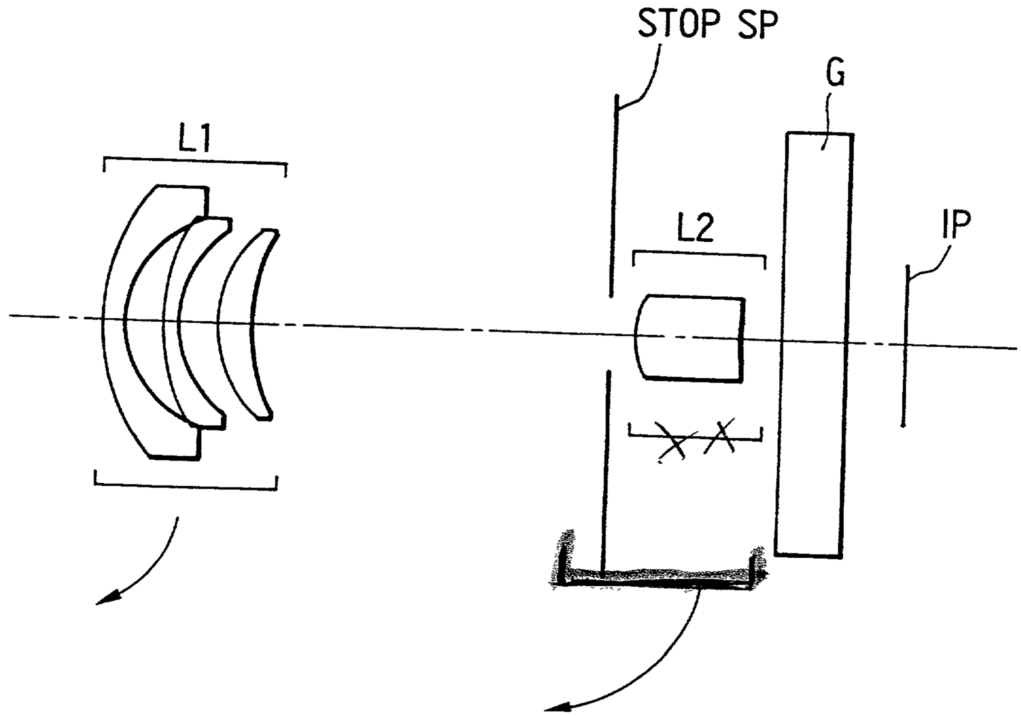
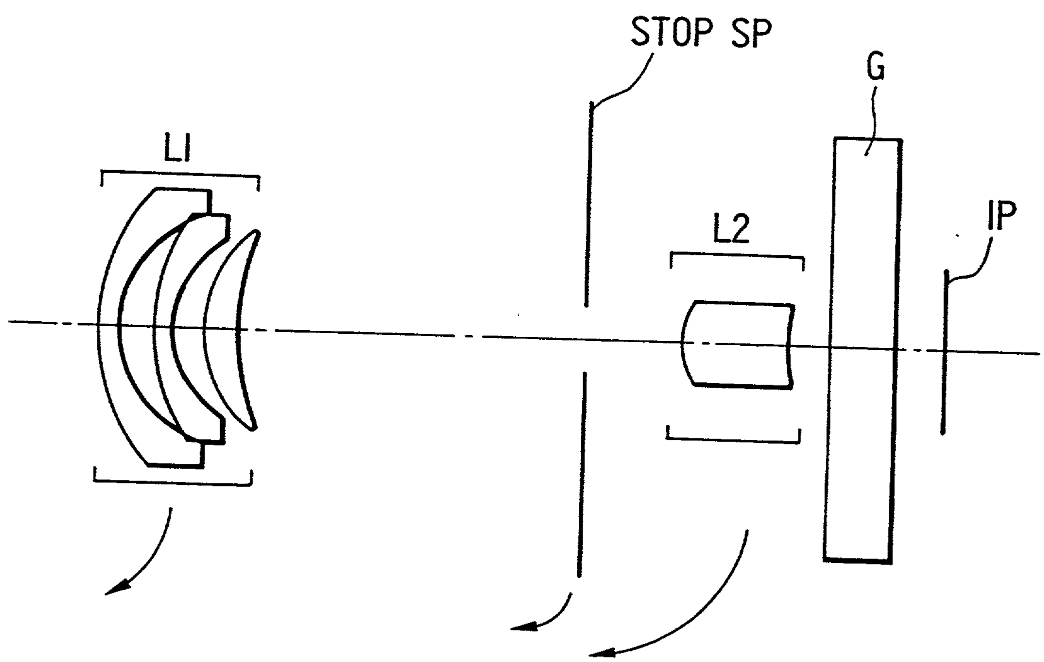


FIG. 4



TITLE OF THE INVENTION

ZOOM LENS AND PHOTOGRAPHING APPARATUS HAVING THE SAME

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to zoom lenses suited to cameras for photography, video cameras and still video cameras.

Description of Related Art

A type of zoom lens in which the preceding lens unit is negative in refractive power, or the so-called negative lead type, is feasible for widening the angle of view with relative ease, so that the negative lead type zoom lens has found its use as the standard zoom lens in many cameras.

Of the standard lenses of the above type, there is a one which is constructed with a first lens unit of negative refractive power and a second lens unit of positive refractive power, totaling two lens units, the arrangement being made such that these two lens units move along a common optical axis in differential relation to vary the focal length, or the so-called 2-unit zoom lens, as, for example, proposed in Japanese Laid-Open Patent Applications No. Sho 53-132360 (corresponding to U.S. Patent No. 4,299,452), No. Sho 56-19022 (corresponding to U.S. Patent No. 4,370,031) and U.S. Patent No. 5,283,639.

For such 2-unit zoom lenses, the use of many aspheric surfaces reduces the number of constituent lenses to a compact form, as, for example, proposed in

Japanese Laid-Open Patent Applications No. Hei 4-46308, No. Hei 4-46309, No. Hei 4-46310, No. Hei 4-56814, No. Hei 4-67112, No. Hei 4-67113 and No. Hei 9-33810.

Also, in Japanese Patent Publication No. Sho 60-46688 and Japanese Laid-Open Patent Application No. Hei 5-88084, a compact zoom lens is disclosed, in which the first lens unit is constructed with a negative lens and a positive lens, totaling two lenses, and the second lens unit is constructed with a positive lens, a positive lens, a negative lens and a positive lens, totaling four lenses. In Japanese Patent Publication No. Sho 61-42246, the first lens unit is constructed with a negative lens and a positive lens, totaling two lenses, and the second lens unit is constructed with four or five lenses.

In general, the negative lead type zoom lens comprising the first lens unit of negative refractive power and the second lens unit of positive refractive power has not only the advantage that the maximum field angle is relatively easy to increase but also the advantage that a certain back focal distance is easy to obtain.

However, to simultaneously fulfill the requirements of making the entire lens system from as few lens elements as 4 to 8 and of obtaining a good optical performance, there is need to appropriately determine the refractive power arrangement of all the lens elements in each unit, the forms of the lens elements and others. If these are inappropriate, the aberrations, during zooming,

vary to large extent, which cannot be remedied even if the number of lens elements is increased. Therefore, it becomes difficult to attain good stability of high optical performance throughout the entire zooming range.

For example, the zoom lens proposed in the above Japanese Laid-Open Patent Application No. Hei 9-33810, although its having a few lens elements, employs many aspheric surfaces. For this reason, the tolerances on manufacturing become very severe. So, there is a difficult problem of axially aligning all the lens elements with high accuracy in finish.

Even in another U.S. Patent No. 4,999,007, a zoom lens with a smaller number of lens elements is proposed. Particularly for the first and second embodiments in this patent, a range of not less than 3 is realized, but the number of constituent lenses in the first lens unit is as few as 1 or 2. Accordingly, the aberrations the first lens unit produces, including chromatic aberrations, are failed to correct well enough. Also, the aspherical first lens of the first embodiment has so unfavorable a form as to make with ease by using molding techniques. Concretely speaking, the paraxial and marginal zones largely differ in thickness. Therefore, as it takes the form in the mold, the lens is hardly detached from the mold. In the second embodiment, the above-described drawback is short, but the angle of view is narrow, suggesting that the design does not aim at extending the wide angle end toward sufficiently

shorter focal lengths. In addition, the entire lens system has a long total length and is not suited to improve the compact form.

BRIEF SUMMARY OF THE INVENTION

The present invention is to employ the negative lead type in the zoom lens and sets forth proper rules of design for the form and the construction and arrangement of the constituent lenses in each lens unit. It is, therefore, an object of the invention to provide a zoom lens which is simplified in design, while still permitting the optical performance to be maintained stable at a high level throughout the entire zooming range and at a high quality over all the area of the image frame.

To attain the above object, in accordance with an aspect of the invention, there is provided a zoom lens, which comprises, in order from an object side, a first lens unit of negative refractive power and a second lens unit of positive refractive power, wherein variation of magnification is effected by varying a separation between the first lens unit and the second lens unit, the zoom lens satisfying the following conditions:

$$3 \leq NL1 \leq 4 \quad \ldots (1)$$

$$NL2 \leq NL1 \quad \ldots (2)$$

where NL1 and NL2 are numbers of lens elements which constitute the first lens unit and the second lens unit, respectively.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

Fig. 1 is a longitudinal section view of a numerical example 1 of the zoom lens in the wide-angle end.

Fig. 2 is a longitudinal section view of a numerical example 2 of the zoom lens in the wide-angle end.

Fig. 3 is a longitudinal section view of a numerical example 3 of the zoom lens in the wide-angle end.

Fig. 4 is a longitudinal section view of a numerical example 4 of the zoom lens in the wide-angle end.

Fig. 5 is a longitudinal section view of a numerical example 5 of the zoom lens in the wide-angle end.

Fig. 6 is a longitudinal section view of a numerical example 6 of the zoom lens in the wide-angle end.

Fig. 7 is a longitudinal section view of a numerical example 7 of the zoom lens in the wide-angle end.

Fig. 8 is a longitudinal section view of a numerical example 8 of the zoom lens in the wide-angle end.

Fig. 9 is a longitudinal section view of a numerical example 9 of the zoom lens in the wide-angle end.

Figs. 10A to 10D are graphic representations of the various aberrations of the numerical example 1 in the wide-angle end.

Figs. 11A to 11D are graphic representations of the various aberrations of the numerical example 1 in the telephoto end.

Figs. 12A to 12D are graphic representations of the various aberrations of the numerical example 2 in the wide-angle end.

Figs. 13A to 13D are graphic representations of the various aberrations of the numerical example 2 in the telephoto end.

Figs. 14A to 14D are graphic representations of the various aberrations of the numerical example 3 in the wide-angle end.

Figs. 15A to 15D are graphic representations of the various aberrations of the numerical example 3 in the telephoto end.

Figs. 16A to 16D are graphic representations of the various aberrations of the numerical example 4 in the wide-angle end.

Figs. 17A to 17D are graphic representations of the various aberrations of the numerical example 4 in the telephoto end.

Figs. 18A to 18D are graphic representations of the various aberrations of the numerical example 5 in the wide-angle end.

Figs. 19A to 19D are graphic representations of

the various aberrations of the numerical example 5 in the telephoto end.

Figs. 20A to 20D are graphic representations of the various aberrations of the numerical example 6 in the wide-angle end.

Figs. 21A to 21D are graphic representations of the various aberrations of the numerical example 6 in the telephoto end.

Figs. 22A to 22D are graphic representations of the various aberrations of the numerical example 7 in the wide-angle end.

Figs. 23A to 23D are graphic representations of the various aberrations of the numerical example 7 in the telephoto end.

Figs. 24A to 24D are graphic representations of the various aberrations of the numerical example 8 in the wide-angle end.

Figs. 25A to 25D are graphic representations of the various aberrations of the numerical example 8 in the telephoto end.

Figs. 26A to 26D are graphic representations of the various aberrations of the numerical example 9 in the wide-angle end.

Figs. 27A to 27D are graphic representations of the various aberrations of the numerical example 9 in the telephoto end.

Figs. 28A and 28B are schematic diagrams for explaining an embodiment of the photographing apparatus.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, preferred embodiments of the invention will be described in detail with reference to the drawings.

Figs. 1 to 9 are lens block diagrams showing numerical examples 1 to 9 of the zoom lenses according to an embodiment of the invention, respectively. In Figs. 1 to 9, reference character L1 denotes a first lens unit of negative refractive power, reference character L2 denotes a second lens unit of positive refractive power, reference character SP denotes a stop, and reference character IP denotes an image plane at which an image pickup element such as CCD is disposed. Reference character G denotes a glass block such as a filter or a phase plate. During zooming from the wide-angle end to the telephoto end, the first and second lens units axially move toward the object side, while reducing the separation therebetween, as indicated by the arrows in Figs. 1 to 9. In the present embodiment, the function of varying the focal length is realized mainly by moving the second lens unit. The shift of the image plane with variation of the focal length is compensated for by moving the first lens unit. The stop SP axially moves toward the object side during zooming either independently of the first and second lens units or in unison with the second lens unit. Focusing is performed by moving the first or second lens unit or the entire lens system.

In the present embodiment, for the first and second lens units, the numbers of lens elements to be used are so determined as to satisfy the conditions (1) and (2) described above. The lens design is thus simplified. Nonetheless, a good optical performance is obtained throughout the entire zooming range and over all the entire area of an image frame.

Next, the technical significance of each of the above-described conditions (1) and (2) is explained below.

The inequalities of condition (1) represent a condition necessary for the 2-unit zoom lens to insure that the lens system is suppressed in bulk and size from increasing greatly, without causing the first lens unit to produce large aberrations. They relate also to the necessity of simultaneously assuring that any of the lens elements constituting the first lens unit does not take an unfavorable form for economical production by molding.

It is preferred to construct the first lens unit with inclusion of at least one positive lens and the second lens unit with inclusion of at least one negative lens, so that each lens unit is suppressed from producing aberrations including chromatic ones. Here, if the first lens unit is composed of only one negative lens, the refractive power of that negative lens becomes too much strong so that the distortion increases greatly. Another problem is that, to make a photographic lens whose field angle is wide enough, the difference in thickness between the paraxial and marginal zones of the negative lens

becomes too large to use the molding technique. To avoid these at once, it is preferred that the first lens unit has two or more negative lenses which take equal shares of the negative refractive power to each other.

Further, after the first lens unit has thus been corrected for the aberrations to a minimum, the second lens unit as the main variator has to co-operate so that the entire lens system is sufficiently reduced in size in such a manner as to suppress the total aberrations to a minimum. For this purpose, it is preferred that the condition (2) described above is satisfied.

In this connection, it is to be noted that the first lens unit has at least one aspheric surface. With this aspheric surface, even when the number of constituent lenses is relatively few, the image aberrations can be corrected advantageously.

In actual practice, the first lens unit is made constructed with inclusion of, in order from the object side, two negative lenses each having a concave surface toward the image side and a positive lens having a convex surface facing the object side.

Now, in relation to the values of the factor NL2 described above, the invention sets forth rules of design for the second lens unit as follows.

(a-1) When the number of lens elements "NL2" is NL2 = 1, the Abbe number νP of the material of the lens element constituting the second lens unit lies within the following range:

$$50 < \nu P$$

This is a desired condition on correction of chromatic aberrations for good stability during zooming. To further reduce the chromatic aberrations, it is preferred to satisfy the following condition:

$$75 < \nu P$$

(a-2) When the number of lens elements "NL2" is NL2 = 2, it is preferred that the second lens unit consists of, in order from the object side, a positive lens of bi-convex form and a negative lens having a concave surface of stronger refractive power facing the image side than that of an opposite surface thereof.

In particular, the positive lens of bi-convex form has a convex surface of stronger curvature facing the object side than that of an opposite surface thereof, and the negative lens is in the form of a meniscus lens concave toward the image side.

(a-3) When the number of lens elements "NL2" is NL2 = 3, it is preferred that the second lens unit includes a negative lens of meniscus form concave toward the image side.

It should be also pointed out that, if the second lens unit is composed of, in order from the object side, a positive lens of bi-convex form having a convex surface of stronger curvature facing the object side than that of an opposite surface thereof, a negative lens of meniscus form having a concave surface of stronger curvature facing the image side than that of an opposite

surface thereof and a positive lens, the back focal distance is suitably increased to increase the distance of the exit pupil.

Further, the second lens unit contributes to a major variation of the focal length of the zoom lens, and the amount of movement of the second lens unit for variation of the focal length, too, is large. For this reason, it is better that the second lens unit is small in size and light in weight in view of moving the second lens unit as a system. Concretely speaking, the second lens unit comprises, in order from the object side:

(i) one positive lens alone;

(ii) one positive lens and one negative lens;

(iii) a positive lens, a negative lens and a positive lens; or

(iv) a positive lens, a positive lens, a negative lens and a positive lens.

Any of these constructions and arrangements is preferable. In the cases of (i), (ii) and (iii), it is preferred to provide the second lens unit with at least one aspheric surface. Even in the case of (iv), the aspheric surface may be employed, but it is possible to leave that surface in the spherical form. (In this case, although depending on the degree of balance of the corrected aberrations, this construction is rather preferable when the first lens unit is made from four lens elements).

Further, it is preferred that the aperture stop

is disposed in the space between the first and second lens units.

The zoom lens of the invention has its constituent lens elements made to take various forms in each lens unit. These forms are described below.

(b-1) The first lens unit consists of two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side. The second lens unit consists of a positive lens of bi-convex form and a negative lens having a concave surface facing the image side.

(b-2) The first lens unit consists of two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side. The second lens unit consists of a positive lens of meniscus form convex toward the object side.

(b-3) The first lens unit consists of two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side. The second lens unit consists of a positive lens of bi-convex form, a negative lens of meniscus form convex toward the object side and a positive lens of bi-convex form.

(b-4) The first lens unit consists of a positive lens of bi-convex form, two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side. The second lens unit consists of a positive lens of bi-convex form

and a negative lens having a concave surface facing the image side.

(b-5) The first lens unit consists of a positive lens of bi-convex form, two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side. The second lens unit consists of a positive lens of bi-convex form, a negative lens of meniscus form convex toward the object side and a positive lens of bi-convex form.

(b-6) The first lens unit consists of a positive lens of bi-convex form, two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side. The second lens unit consists of a positive lens of bi-convex form, a positive lens of meniscus form convex toward the object side, a negative lens of bi-concave form and a positive lens of bi-convex form.

(b-7) The first lens unit consists of a positive lens of bi-convex form, two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side. The second lens unit consists of a positive lens of bi-convex form.

The characteristic features of the lens design of the numerical examples 1 to 9 are described below.

(Numerical Example 1 (Fig. 1))

The forms and the construction and arrangement of the constituent lenses of the numerical example 1 are similar to those of the prescript (b-1) described above.

This zoom lens has an aperture stop SP disposed in the space between the first and second lens units and arranged to axially move independently of the lens units during zooming.

In the numerical example 1, as the stop SP moves slightly during zooming, it may be made completely fixed instead. An aspheric surface is put in the one of the negative lenses of the first lens unit which is smaller in diameter than the other at the rear surface (the fourth surface) thereof, thus taking it into account that the difference in thickness between the paraxial and marginal zones does not become so large that the form becomes unfavorable for making the aspherical lens by molding. For this purpose, the negative lens that contributes to the negative refractive power of the first lens unit is made two in number.

The second lens unit is constructed with two lenses. Its frontmost surface (the eighth surface) is made aspherical to remove spherical aberration and coma, and its rearmost surface (the eleventh surface), too, is made aspherical to remove spherical aberration and curvature of field.

(Numerical Example 2 (Fig. 2))

The zoom lens of the numerical example 2 is also designed based on the prescript (b-1) and has an aperture stop SP disposed adjacent to the second lens unit on the object side thereof.

In the numerical example 2, the stop SP moves

together with the second lens unit. For the first lens unit, from the same reason as described before, two negative lenses are used so that the one which is smaller in diameter is made aspherical at the rear surface (the fourth surface) thereof.

For the second lens unit with two lenses, the frontmost surface (the eighth surface) is made aspherical to remove spherical aberration and coma and the rearmost surface (the eleventh surface), too, is made aspherical to remove spherical aberration and curvature of field.

(Numerical Example 3 (Fig. 3))

The form and the construction and arrangement of the constituent lenses of the numerical example 3 are similar to the prescript (b-2). The numerical example 3 has an aperture stop SP disposed adjacent to the second lens unit on the object side thereof.

In the numerical example 3, too, the stop SP moves together with the second lens unit. An aspheric surface is put in the one of the negative lenses of the first lens unit which is smaller in diameter than the other at the rear surface (the fourth surface) thereof, thus taking it into account that the difference in thickness between the paraxial and marginal zones does not become so large that the form becomes unfavorable for making the aspherical lens by molding. For this purpose, the negative lens that contributes to the negative refractive power of the first lens unit is made two in number.

The second lens unit is constructed with only one positive lens of meniscus form, whose front surface (the eighth surface) is made aspherical to remove spherical aberration and coma. Another aspheric surface is provided in the rear surface (the ninth surface) to remove spherical aberration and curvature of field.

(Numerical Example 4 (Fig. 4))

The lens units of the numerical example 4 are designed also based on the prescript (b-2) cited above. The numerical example 4 has an aperture stop SP disposed in the space between the first and second lens units and arranged to axially move independently of the lens units during zooming.

In the numerical example 4, the stop SP moves slightly during zooming, but may be made completely fixed instead. An aspheric surface is put in the one of the negative lenses of the first lens unit which is smaller in diameter than the other at the rear surface (the fourth surface) thereof, thus taking it into account that the difference in thickness between the paraxial and marginal zones does not become so large that the form becomes unfavorable for making the aspherical lens by molding. For this purpose, the negative lens that contributes to the negative refractive power of the first lens unit is made two in number.

The second lens unit is constructed with only one positive lens of meniscus form. Because the number of constituent lenses is very few, the glass to be used

is made especially little in dispersion for the purpose of removing chromatic aberrations.

In particular, the front surface (the eighth surface) is made aspherical to remove spherical aberration and coma. Even the rear surface (the ninth surface) is provided with another aspheric surface to remove spherical aberration and curvature of field.

(Numerical Example 5 (Fig. 5))

The zoom lens of the numerical example 5 is designed based on the prescript (b-3) and has an aperture stop SP disposed in the space between the first and second lens units and arranged to axially move independently of the lens units during zooming.

In the numerical example 5, the stop SP moves slightly during zooming, but may be made completely fixed instead. An aspheric surface is put in the one of the negative lenses of the first lens unit which is smaller in diameter than the other at the rear surface (the fourth surface) thereof, thus taking it into account that the difference in thickness between the paraxial and marginal zones does not become so large that the form becomes unfavorable for making the aspherical lens by molding. For this purpose, the negative lens that contributes to the negative refractive power of the first lens unit is made two in number.

The second lens unit is constructed with three lenses, i.e., a positive lens, a negative lens and a positive lens.

More specifically, a positive lens of bi-convex form having a convex surface of stronger curvature facing the object side than that of an opposite surface thereof, a negative lens of meniscus form concave toward the image side and a positive lens are arranged in this order from the object side in the second lens unit. This arrangement is suited particularly to an increase in the back focal distance and, therefore, to an increase in the distance of the exit pupil. In particular, the frontmost surface (the eighth surface) is made aspherical to remove spherical aberration and coma.

(Numerical Example 6 (Fig. 6))

The zoom lens of the numerical example 6 is designed based on the prescript (b-4) and has an aperture stop SP disposed in the space between the first and second lens units and arranged to axially move independently of the lens units during zooming.

In the numerical example 6, the stop SP moves slightly during zooming, but may be made completely fixed instead.

The first lens unit is constructed with four spherical lenses, differing from the numerical examples 1 to 5 in that the distortion the first lens unit otherwise made would produce is removed not by the aspherical surface that is difficult to make by molding, but adequately by using a positive lens as arranged on the object side.

The second lens unit is constructed with two

lenses, i.e., a positive lens having a convex surface of stronger curvature facing the object side than that of an opposite surface thereof and a negative lens having a concave surface of stronger curvature facing the image side than that of an opposite surface thereof. In the numerical example 6, the lenses constituting the second lens unit are the positive one of bi-convex form and the negative one of bi-concave form. In particular, for the positive lens, the front surface (the eighth surface) is made aspherical to remove spherical aberration and coma. Even for the negative lens, the rear surface (the thirteenth surface) is provided with an aspheric surface to remove spherical aberration and curvature of field.

(Numerical Example 7 (Fig. 7))

The zoom lens of the numerical example 7 is designed based on the prescript (b-5) and has an aperture stop SP disposed in the space between the first and second lens units and arranged to axially move independently of the lens units during zooming.

Even in the numerical example 7, the stop SP moves slightly during zooming, but may be made completely fixed instead.

The first lens unit is constructed with four spherical lenses, differing from the numerical examples 1 to 5 in that, similarly to the numerical example 6, the distortion the first lens unit otherwise made would produce is removed not by the aspherical surface that is difficult to make by molding, but adequately by using a

positive lens as arranged on the object side.

The second lens unit is constructed with three lenses, i.e., a positive lens, a negative lens and a positive lens.

More specifically, a positive lens of bi-convex form having a convex surface of stronger curvature facing the object side than that of an opposite surface thereof, a negative lens of meniscus form concave toward the image side and a positive lens are arranged in this order from the object side in the second lens unit. This arrangement is particularly suited to an increase in the back focal distance and, therefore, to an increase in the distance of the exit pupil. In particular, for the front one of the positive lenses, the front surface (the tenth surface) is provided with an aspheric surface for removing spherical aberration and coma.

(Numerical Example 8 (Fig. 8))

The zoom lens of the numerical example 8 is designed based on the prescript (b-6) and has an aperture stop SP disposed in the space between the first and second lens units and arranged to axially move independently of the lens units during zooming.

Even in the numerical example 8, the stop SP moves slightly during zooming, but may be made completely fixed instead.

The numerical example 8 has its first lens unit made with four spherical lenses and its second lens unit also with four spherical lenses, thus removing the

distortion the first lens unit otherwise made would produce adequately by using not the aspherical surface that is difficult to make by molding, but additional positive lenses as arranged on the object side of either of the lens units. Further, spherical aberration and coma are removed by increasing the number of spherical lenses, especially positive lenses.

More specifically, the second lens unit consists of, in order from the object side, a positive lens of bi-convex form having a convex surface of stronger curvature facing the object side than that of an opposite surface thereof, a positive lens of meniscus form concave toward the image side, a negative lens of bi-concave form and a positive lens, thereby giving an advantage of removing spherical aberration and coma.

(Numerical Example 9 (Fig. 9))

The zoom lens of the numerical example 9 is designed based on the prescript (b-7). Also, the first lens unit is, similarly to the numerical examples 6, 7 and 8, constructed with four lenses and the second lens unit with a positive lens of bi-convex form, thereby effecting similar results to those of the above examples.

Next, the numerical data for the nine numerical examples 1 to 9 of the invention are shown in tables, where Ri is the radius of curvature of the i-th lens surface, when counted from the object side, Di is the i-th axial lens thickness or air separation, when counted from the object side, and Ni and νi are respectively the

refractive index and Abbe number of the material of the i-th optical element, when counted from the object side.

The shape of an aspheric surface is expressed in the coordinates with an X axis in the axial directions (in which light advances) and a Y axis in the direction perpendicular to an optical axis, by the following equation:

$$X = \frac{(1/R)Y^2}{1+\sqrt{1-(1+K)(Y/R)^2}} + AY^2+BY^4+CY^6+DY^8+EY^{10}$$

where R is the radius of the osculating sphere, and K, A, B, C, D and E are the aspheric coefficients.
In the values of the aspheric coefficients, the notation: "e-X" means "$\times 10^{-X}$".

The aberrations for the wide-angle end of the zoom lens of the numerical example 1 are shown in Figs. 10A to 10D, and the aberrations for the telephoto end in Figs. 11A to 11D. The aberrations for the wide-angle end of the zoom lens of the numerical example 2 are shown in Figs. 12A to 12D, and the aberrations for the telephoto end in Figs. 13A to 13D. The aberrations for the wide-angle end of the zoom lens of the numerical example 3 are shown in Figs. 14A to 14D, and the aberrations for the telephoto end in Figs. 15A to 15D. The aberrations for the wide-angle end of the zoom lens of the numerical example 4 are shown in Figs. 16A to 16D, and the aberrations for the telephoto end in Figs. 17A to 17D. The aberrations for the wide-angle end of the

zoom lens of the numerical example 5 are shown in Figs. 18A to 18D, and the aberrations for the telephoto end in Figs. 19A to 19D. The aberrations for the wide-angle end of the zoom lens of the numerical example 6 are shown in Figs. 20A to 20D, and the aberrations for the telephoto end in Figs. 21A to 21D. The aberrations for the wide-angle end of the zoom lens of the numerical example 7 are shown in Figs. 22A to 22D, and the aberrations for the telephoto end in Figs. 23A to 23D. The aberrations for the wide-angle end of the zoom lens of the numerical example 8 are shown in Figs. 24A to 24D, and the aberrations for the telephoto end in Figs. 25A to 25D. The aberrations for the wide-angle end of the zoom lens of the numerical example 9 are shown in Figs. 26A to 26D, and the aberrations for the telephoto end in Figs. 27A to 27D.

Numerical Example 1:

f= 1~3.18 Fno= 2.69~5.65 2ω= 66.3°~23.2°

R 1= 3.038	D 1= 0.27	N 1= 1.772499	ν 1= 49.6
R 2= 1.352	D 2= 0.31		
R 3= 3.049	D 3= 0.21	N 2= 1.693501	ν 2= 53.2
R 4= 1.329	D 4= 0.63		
R 5= 2.036	D 5= 0.40	N 3= 1.698947	ν 3= 30.1
R 6= 4.030	D 6= Variable		
R 7= Stop	D 7= Variable		
R 8= 1.147	D 8= 0.69	N 4= 1.583126	ν 4= 59.4
R 9= -2.254	D 9= 0.04		

R10= -26.583 D10= 0.72 N 5= 1.805181 ν 5= 25.4

R11= 1.685 D11= Variable

G R12= ∞ D12= 0.83 N 6= 1.516330 ν 6= 64.2

R13= ∞

Variable Separation	Focal Length		
	1.00	2.70	3.18
D 6	2.70	0.43	0.39
D 7	2.04	0.59	0.29
D11	0.53	1.89	2.28

Aspheric Coefficients:

R 4: K=-7.52762e-01 B=-1.40160e-02 C= 1.28780e-02

D=-3.58445e-03 E=-1.65803e-03

R 8: K=-4.08535e-01 B=-3.39944e-02 C=-5.36474e-02

D= 1.26615e-02 E=-1.78521e-02

R11: K= 4.02997e+00 B= 1.29346e-01 C=-6.10686e-02

D= 8.45058e-02 E=-8.09831e-01

Numerical Example 2:

f= 1~3.15 Fno= 2.85~5.65 2ω= 66.3°~23.4°

R 1= 2.917 D 1= 0.27 N 1= 1.772499 ν 1= 49.6

R 2= 1.371 D 2= 0.36

R 3= 2.803 D 3= 0.21 N 2= 1.693501 ν 2= 53.2

R 4= 1.268 D 4= 0.64

R 5= 1.712 D 5= 0.40 N 3= 1.698947 ν 3= 30.1

R 6= 2.503 D 6= Variable

R 7= Stop D 7= 0.29

R 8= 1.127 D 8= 0.69 N 4= 1.583126 ν 4= 59.4

R 9= -2.352 D 9= 0.04

R10= 306.001 D10= 0.72 N 5= 1.846660 ν 5= 23.8

R11= 1.745 D11= Variable

G R12= ∞ D12= 0.83 N 6= 1.516330 ν 6= 64.2

R13= ∞

Variable Separation	Focal Length		
	1.00	2.68	3.15
D 6	3.89	0.73	0.45
D11	0.53	1.95	2.35

Aspheric Coefficients:

R 4: K=-1.20367e+00 B= 3.30556e-02 C= 7.80093e-03

D=-6.28237e-03 E= 7.51183e-04

R 8: K=-5.02004e-01 B=-2.86958e-02 C=-5.57241e-02

D= 4.16164e-02 E=-4.39216e-02

R11: K= 3.95146e+00 B= 1.26054e-01 C=-3.70316e-02

D= 1.11331e+00 E=-8.41197e+00

Numerical Example 3:

f= 1~2.65 Fno= 2.85~4.53 2ω= 66.3°~27.6°

R 1= 2.851 D 1= 0.27 N 1= 1.719995 ν 1= 50.2

R 2= 1.458 D 2= 0.45

R 3= 2.563 D 3= 0.21 N 2= 1.693501 ν 2= 53.2

R 4= 1.317 D 4= 0.51

R 5= 1.755 D 5= 0.40 N 3= 1.698947 ν 3= 30.1

R 6= 2.575 D 6= Variable

R 7= Stop D 7= 0.29

R 8= 1.072 D 8= 1.33 N 4= 1.583126 ν 4= 59.4

R 9= 4.825 D 9= Variable

G R10= ∞ D10= 0.83 N 5= 1.516330 ν 5= 64.2

R11= ∞

Variable Separation	Focal Length		
	1.00	2.29	2.65
D 6	4.48	0.83	0.44
D 9	0.53	1.40	1.65

Aspheric Coefficients:

R 4: K=-1.66705e+00 B= 6.47571e-02 C=-1.80043e-03

D=-7.71257e-03 E= 1.52496e-03

R 8: K= 1.87950e-01 B=-3.78366e-02 C=-4.27240e-02

D= 5.35924e-02 E=-2.12822e-01

R 9: K= 2.07670e+01 B= 2.46411e-01 C= 1.70155e-01

D= 1.20576e+00 E=-3.19385e+00

Numerical Example 4:

f= 1~2.57 Fno= 2.85~4.18 2ω= 64.4°~27.6°

R 1= 2.676 D 1= 0.26 N 1= 1.696797 ν 1= 55.5

R 2= 1.510 D 2= 0.42

R 3= 2.624 D 3= 0.21 N 2= 1.693501 ν 2= 53.2

R 4= 1.148 D 4= 0.39

R 5= 1.666 D 5= 0.39 N 3= 1.698947 ν 3= 30.1

R 6= 3.315 D 6= Variable

R 7= Stop D 7= Variable

R 8= 0.900 D 8= 1.28 N 4= 1.496999 ν 4= 81.5

R 9= 3.814 D 9= Variable

G R10= ∞ D10= 0.80 N 5= 1.516330 ν 5= 64.2

R11= ∞

Variable Separation	Focal Length		
	1.00	2.22	2.57
D 6	4.20	0.80	0.44
D 7	1.16	0.39	0.28
D 9	0.51	1.20	1.39

Aspheric Coefficients:

R 4: K=-1.81994e+00 B= 1.06357e-01 C=-3.27203e-03

D=-9.67866e-03 E= 2.57786e-03

R 8: K=-7.07393e-02 B=-4.42876e-02 C=-9.75518e-02

D= 5.88472e-01 E=-1.46412e+00

R 9: K= 4.30997e+01 B= 2.90520e-01 C= 2.79491e-01

D= 2.32650e+00 E=-5.61094e+00

Numerical Example 5:

f= 1~2.94 Fno= 2.85~5.45 2ω= 66.2°~25.0°

R 1= 2.652 D 1= 0.27 N 1= 1.719995 ν 1= 50.2

R 2= 1.310 D 2= 0.34

R 3= 3.511 D 3= 0.21 N 2= 1.693501 ν 2= 53.2

R 4= 1.332 D 4= 0.55

R 5= 1.876 D 5= 0.40 N 3= 1.846660 ν 3= 23.8

R 6= 2.795 D 6= Variable

R 7= Stop D 7= Variable

R 8= 1.187 D 8= 0.67 N 4= 1.583126 ν 4= 59.4

R 9= -6.020 D 9= 0.08

R10= 4.554 D10= 0.32 N 5= 1.846660 ν 5= 23.8

R11= 1.058 D11= 0.15

R12= 2.733 D12= 0.40 N 6= 1.806098 ν 6= 40.9

R13= -6.454 D13= Variable

G R14= ∞ D14= 0.82 N 7= 1.516330 ν 7= 64.2

R15= ∞

Variable Separation	Focal Length		
	1.00	2.51	2.94
D 6	2.49	0.43	0.38
D 7	1.98	0.57	0.29
D13	0.53	1.85	2.22

Aspheric Coefficients:

R 4: K=-1.02220e+00 B= 1.54317e-02 C= 9.68593e-03

D=-9.33659e-03 E=-6.59126e-03

R 8: K=-1.83735e+00 B= 7.05969e-02 C=-2.75995e-02

D= 3.18968e-02 E=-1.80873e-02

Numerical Example 6:

f= 1~2.97 Fno= 2.85~5.43 2ω= 66.1°~24.7°

R 1= 28.187 D 1= 0.40 N 1= 1.846660 ν 1= 23.8

R 2= -26.411 D 2= 0.05

R 3= 4.823 D 3= 0.27 N 2= 1.772499 ν 2= 49.6

R 4= 1.788	D 4= 0.31		
R 5= 3.037	D 5= 0.21	N 3= 1.693501	ν 3= 53.2
R 6= 1.324	D 6= 0.63		
R 7= 1.532	D 7= 0.40	N 4= 1.698947	ν 4= 30.1
R 8= 1.934	D 8= Variable		
R 9= Stop	D 9= Variable		
R10= 1.124	D10= 0.69	N 5= 1.583126	ν 5= 59.4
R11= -2.052	D11= 0.04		
R12= -32.290	D12= 0.72	N 6= 1.805181	ν 6= 25.4
R13= 1.742	D13= Variable		
R14= ∞	D14= 0.82	N 7= 1.516330	ν 7= 64.2
R15= ∞			

Variable Separation	Focal Length		
	1.00	2.53	2.97
D 8	2.72	0.54	0.43
D 9	1.66	0.50	0.29
D13	0.53	1.60	1.91

Aspheric Coefficients:

R10: K=-3.82272e-01 B=-5.51425e-02 C=-2.71024e-02

D=-6.56724e-02 E= 4.65365e-02

R13: K= 4.61127e+00 B= 9.79659e-02 C= 2.47713e-01

D=-3.73650e+01 E=-7.28627e-01

Numerical Example 7:

f= 1~2.97 Fno= 2.85~5.33 2ω= 66.1°~24.7°

	R 1= 77.194	D 1= 0.40	N 1= 1.846660	ν 1= 23.8
	R 2= -12.262	D 2= 0.08		
	R 3= 10.325	D 3= 0.27	N 2= 1.772499	ν 2= 49.6
	R 4= 1.805	D 4= 0.31		
	R 5= 3.038	D 5= 0.21	N 3= 1.693501	ν 3= 53.2
	R 6= 1.325	D 6= 0.46		
	R 7= 1.517	D 7= 0.40	N 4= 1.698947	ν 4= 30.1
	R 8= 2.208	D 8= Variable		
	R 9= Stop	D 9= Variable		
	R10= 1.334	D10= 0.64	N 5= 1.583126	ν 5= 59.4
	R11= -4.412	D11= 0.08		
	R12= 8.019	D12= 0.32	N 6= 1.846660	ν 6= 23.8
	R13= 1.314	D13= 0.14		
	R14= 4.223	D14= 0.40	N 7= 1.834000	ν 7= 37.2
	R15= -4.136	D15= Variable		
G	R16= ∞	D16= 0.82	N 8= 1.516330	ν 8= 64.2
	R17= ∞			

Variable Separation	Focal Length		
	1.00	2.53	2.97
D 8	2.70	0.48	0.42
D 9	1.99	0.57	0.28
D15	0.53	1.86	2.24

Aspheric Coefficients:

R10: K= 1.45983e-01 B=-6.79192e-02 C=-2.53234e-02

D=-2.73981e-03 E=-3.31441e-04

Numerical Example 8:

f= 1~2.93   Fno= 2.85~5.15   2ω= 65.9°~24.9°

	R 1= 52.653	D 1= 0.40	N 1= 1.846660	ν 1= 23.8
	R 2= -15.662	D 2= 0.08		
	R 3= 7.326	D 3= 0.26	N 2= 1.772499	ν 2= 49.6
	R 4= 1.845	D 4= 0.31		
	R 5= 3.025	D 5= 0.21	N 3= 1.693501	ν 3= 53.2
	R 6= 1.319	D 6= 0.42		
	R 7= 1.521	D 7= 0.40	N 4= 1.625882	ν 4= 35.7
	R 8= 2.364	D 8= Variable		
	R 9= Stop	D 9= Variable		
	R10= 2.473	D10= 0.48	N 5= 1.583126	ν 5= 59.4
	R11= -4.671	D11= 0.05		
	R12= 1.189	D12= 0.48	N 6= 1.658441	ν 6= 50.9
	R13= 2.602	D13= 0.19		
	R14= -9.676	D14= 0.26	N 7= 1.846660	ν 7= 23.8
	R15= 0.993	D15= 0.15		
	R16= 2.436	D16= 0.40	N 8= 1.834000	ν 8= 37.2
	R17= -3.761	D17= Variable		
G	R18= ∞	D18= 0.82	N 9= 1.516330	ν 9= 64.2
	R19= ∞			

Variable Separation	Focal Length		
	1.00	1.97	2.93
D 8	2.98	0.87	0.45
D 9	1.63	0.77	0.18
D17	0.53	1.25	1.97

Numerical Example 9:

f= 1~1.93 Fno= 3.50~4.31 2ω= 53.9°~29.5°

	R 1= 26.066	D 1= 0.31	N 1= 1.834000	ν 1= 87.2
	R 2= -13.666	D 2= 0.06		
	R 3= 5.337	D 3= 0.21	N 2= 1.846680	ν 2= 23.8
	R 4= 2.606	D 4= 0.24		
	R 5= 2.465	D 5= 0.17	N 3= 1.719995	ν 3= 50.2
	R 6= 1.075	D 6= 0.66		
	R 7= 1.265	D 7= 0.31	N 4= 1.834000	ν 4= 37.2
	R 8= 1.505	D 8= Variable		
	R 9= Stop	D 9= Variable		
	R10= 0.874	D10= 1.04	N 5= 1.455999	ν 5= 90.3
	R11= -4.633	D11= Variable		
G	R12= ∞	D12= 0.64	N 6= 1.516330	ν 6= 64.2
	R13= ∞			

Variable Separation	Focal Length		
	1.00	1.47	1.93
D 8	3.32	1.46	0.43
D 9	0.47	0.17	0.07
D11	0.42	0.61	0.81

Aspheric Coefficients:

R10: K=-3.19280e-01 B= 9.51923e-03 C=-2.43528e-02

D= 7.43365e-02 E=-1.37594e+00

R11: K= 1.77845e+01 B= 4.24155e-01 C= 2.71348e-02
D=-4.58833e-04 E=-2.37309e+00

It will be appreciated from the foregoing that, in the zoom lens of a type in which the lens unit of negative refractive power precedes, i.e., the negative lead type, and which comprises two lens units, proper rules of design are set forth for the form and the construction and arrangement of the constituent lenses of each of the lens units. A zoom lens whose angle of view for the wide-angle end is about 66° - 54° and whose zoom ratio is about 2 - 3, with high optical performance maintained stable throughout the entire zooming range, while still permitting assurance of improving the compact form of the entire lens system, is thus made possible to achieve.

In particular, the number of constituent lenses is as far reduced as possible and their forms are made amenable to the low-cost production techniques even by molding. Nonetheless, the image quality is kept good and the F-number becomes fast. Even for the aspherical surfaces, the necessary number is limited to a minimum. So, the zoom lens that has a wide enough field angle and a range of 2 - 3 or thereabout can be produced economically.

Next, an embodiment of a photographing apparatus with the zoom lens of any one of the numerical examples 1 to 9 incorporated therein is described by reference to

Figs. 28A and 28B.

Fig. 28A is a front elevation view of the photographing apparatus and Fig. 28B is a sectional view as viewed from the right side of the same. The photographing apparatus has a body (casing) 10, a photographic optical system 11 using any one of the zoom lenses of the numerical examples 1 to 9, a finder optical system 12 and an image pickup element 13 such as CCD.

In such a manner, the zoom lens of each of the numerical examples 1 - 9 is applied to the photographic optical system of the photographing apparatus, thereby making it possible to realize a compact photographing apparatus.

CLAIMS

1. A zoom lens comprising, in order from an object side to an image side, a first lens unit of negative refractive power and a second lens unit of positive refractive power, wherein variation of magnification is effected by varying a separation between said first lens unit and said second lens unit, said zoom lens satisfying the following conditions:

$$3 \leq NL1 \leq 4$$

$$NL2 \leq NL1$$

where NL1 and NL2 are numbers of lens elements which constitute said first lens unit and said second lens unit, respectively.

2. A zoom lens according to claim 1, wherein, when said number NL2 of lens elements is NL2= 1, the following condition is satisfied:

$$50 < \nu P$$

where νP is an Abbe number of a material of lens elements constituting said second lens unit.

3. A zoom lens according to claim 1, wherein, when said number NL2 of lens elements is NL2 = 2, said second lens unit consists of, in order from the object side to the image side, a positive lens of bi-convex form and a negative lens having a concave surface of stronger refractive power facing the image side than that of an

opposite surface thereof.

4. A zoom lens according to claim 1, wherein, when said number NL2 of lens elements is NL2 = 3, said second lens unit has a negative lens of meniscus form concave toward the image side.

5. A zoom lens according to claim 1, wherein said first lens unit consists of two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side, and said second lens unit consists of a positive lens of bi-convex form and a negative lens having a concave surface facing the image side.

6. A zoom lens according to claim 1, wherein said first lens unit consists of two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side, and said second lens unit consists of a positive lens of meniscus form convex toward the object side.

7. A zoom lens according to claim 1, wherein said first lens unit consists of two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side, and said second lens unit consists of a positive lens of bi-convex form, a negative lens of meniscus form

convex toward the object side and a positive lens of bi-convex form.

8. A zoom lens according to claim 1, wherein said first lens unit consists of a positive lens of bi-convex form, two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side, and said second lens unit consists of a positive lens of bi-convex form and a negative lens having a concave surface facing the image side.

9. A zoom lens according to claim 1, where said first lens unit consists of a positive lens of bi-convex form, two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side, and said second lens unit consists of a positive lens of bi-convex form, a negative lens of meniscus form convex toward the object side and a positive lens of bi-convex form.

10. A zoom lens according to claim 1, wherein said first lens unit consists of a positive lens of bi-convex form, two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side, and said second lens unit consists of a positive lens of bi-convex form, a positive lens of meniscus form convex toward the object side, a

negative lens of bi-concave form and a positive lens of bi-convex form.

11. A zoom lens according to claim 1, wherein said first lens unit consists of a positive lens of bi-convex form, two negative lenses of meniscus form convex toward the object side and a positive lens of meniscus form convex toward the object side, and said second lens unit consists of a positive lens of bi-convex form.

12. A photographing apparatus comprising:

a zoom lens according to one of claims 1 to 11.

ABSTRACT OF THE DISCLOSURE

A zoom lens of the negative lead type includes comprises, in order from an object side, a first lens unit of negative refractive power and a second lens unit of positive refractive power, variation of magnification being effected by varying a separation between the first lens unit and the second lens unit, the zoom lens satisfying the following conditions:

$$3 \leq NL1 \leq 4$$

$$NL2 \leq NL1$$

where NL1 and NL2 are numbers of lens elements which constitute the first lens unit and the second lens unit, respectively.

865.4339 DI

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	
	:	Examiner: M. Lucas
HIROKI NAKAYAMA	)	
	:	Group Art Unit: 2873
Appln. No.: Unassigned (Divisional of Appln. No. 09/248,979 filed February 12, 1999)	) :) :) :	
	)	
Filed: September 12, 2000	:	
	)	
For: ZOOM LENS AND PHOTOGRAPHING APPARATUS HAVING THE SAME	:) :	September 12, 2000

Assistant Commissioner for Patents
BOX PATENT APPLICATION
Washington, DC 20231

LETTER TRANSMITTING CORRECTED FORMAL DRAWINGS

Sir:

Transmitted herewith are two (2) sheets of formal drawings to be substituted for the corresponding drawing sheets presently on file in the above-referenced application.

The new drawing sheets effect the changes set forth in the attached Request for Approval to Amend the Drawings, and were filed in Application No. 09/248,979, the parent of the above-referenced application, on June 21, 1999.

Favorable consideration hereof is requested.

Applicant's undersigned attorney may be reached in our Washington, D.C. office by telephone at (202) 530-1010.

All correspondence should continue to be directed to our below-listed address.

Respectfully submitted,

Attorney for Applicant

Registration No. 28,861

FITZPATRICK, CELLA, HARPER & SCINTO
30 Rockefeller Plaza
New York, New York 10112-3801
Facsimile: (212) 218-2200

GMJ\tnt

FIG. 1

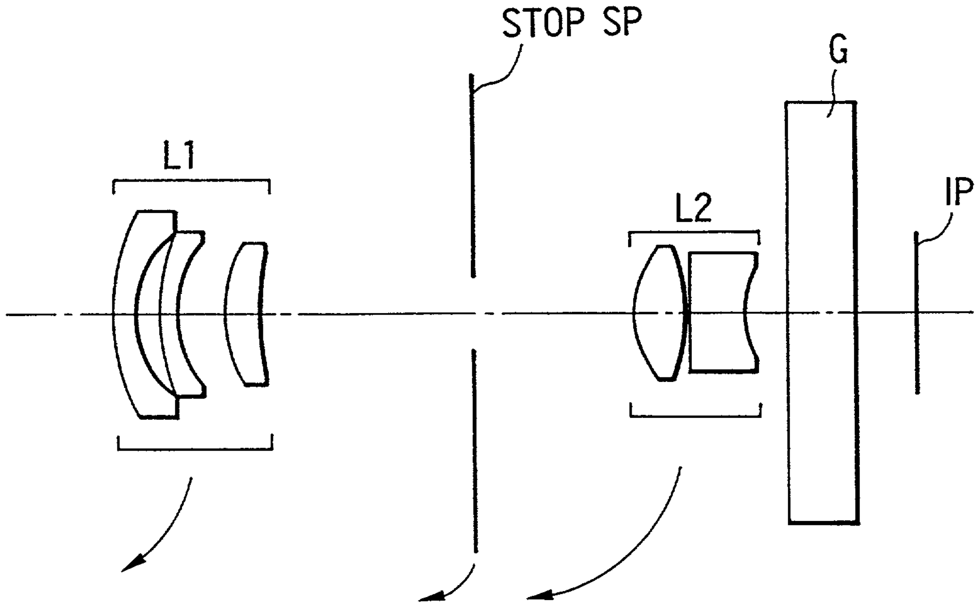


FIG. 2

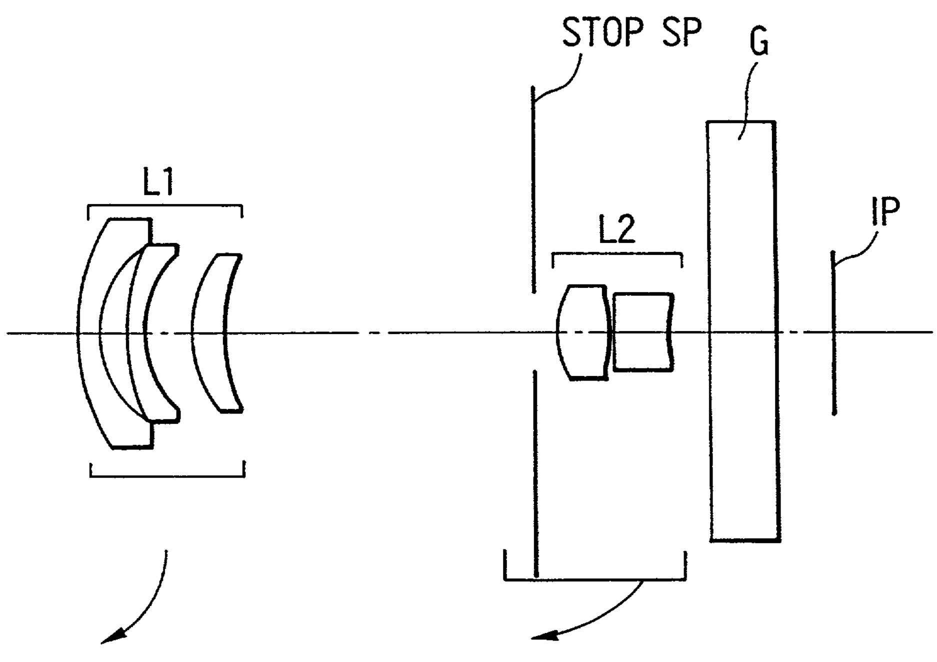


FIG. 3

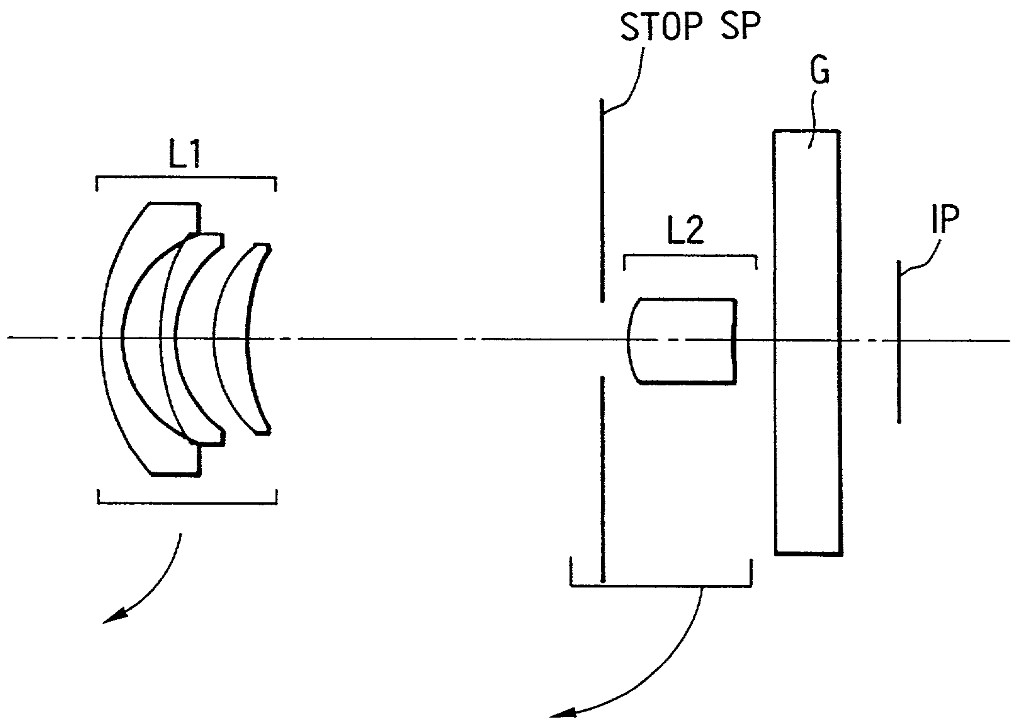


FIG. 4

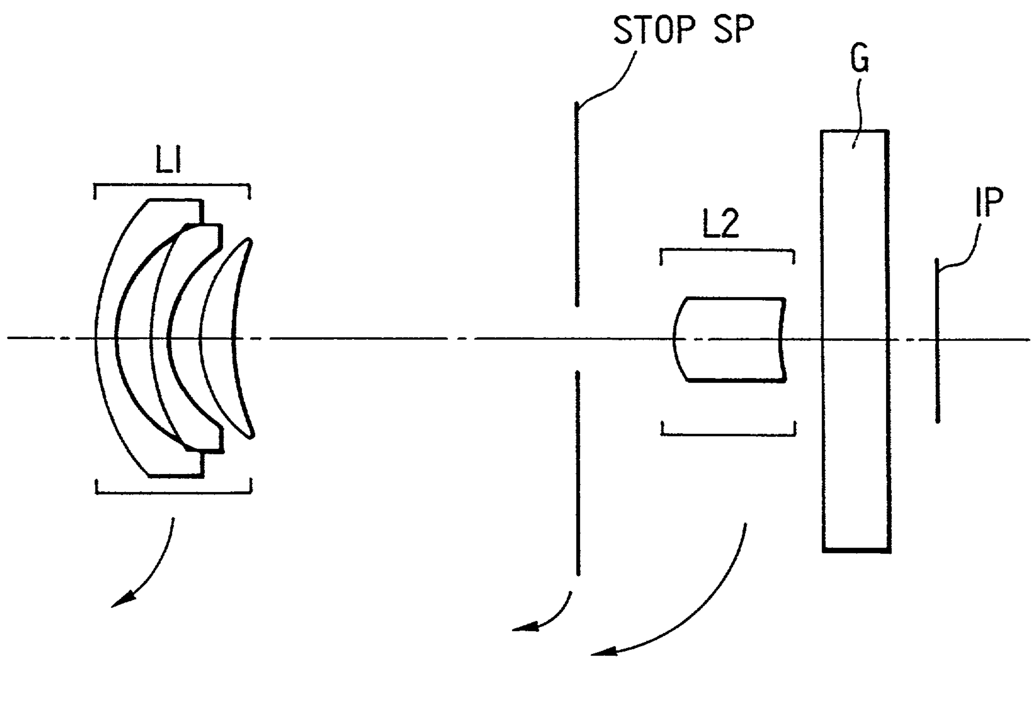


FIG. 1

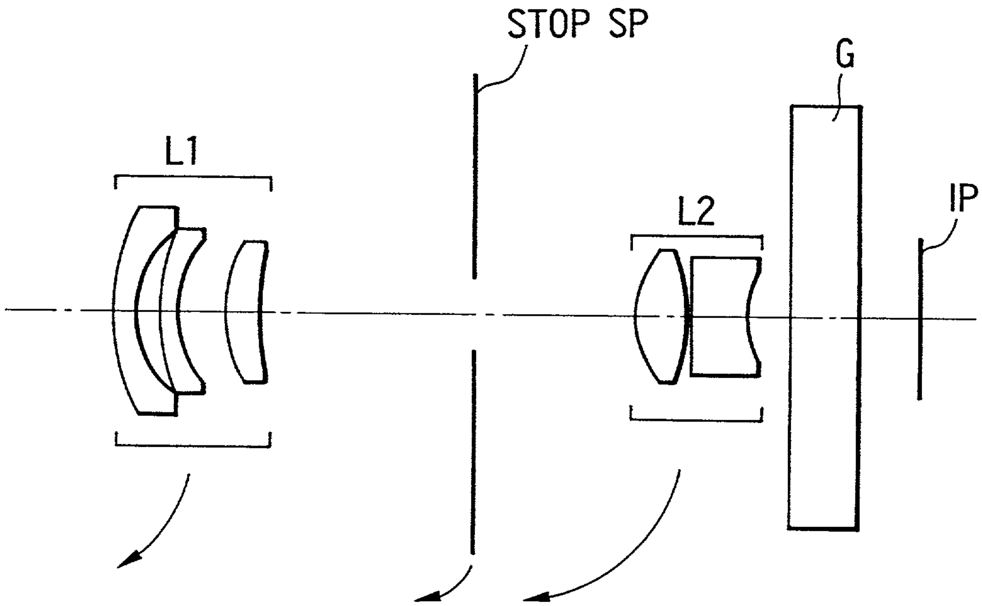


FIG. 2

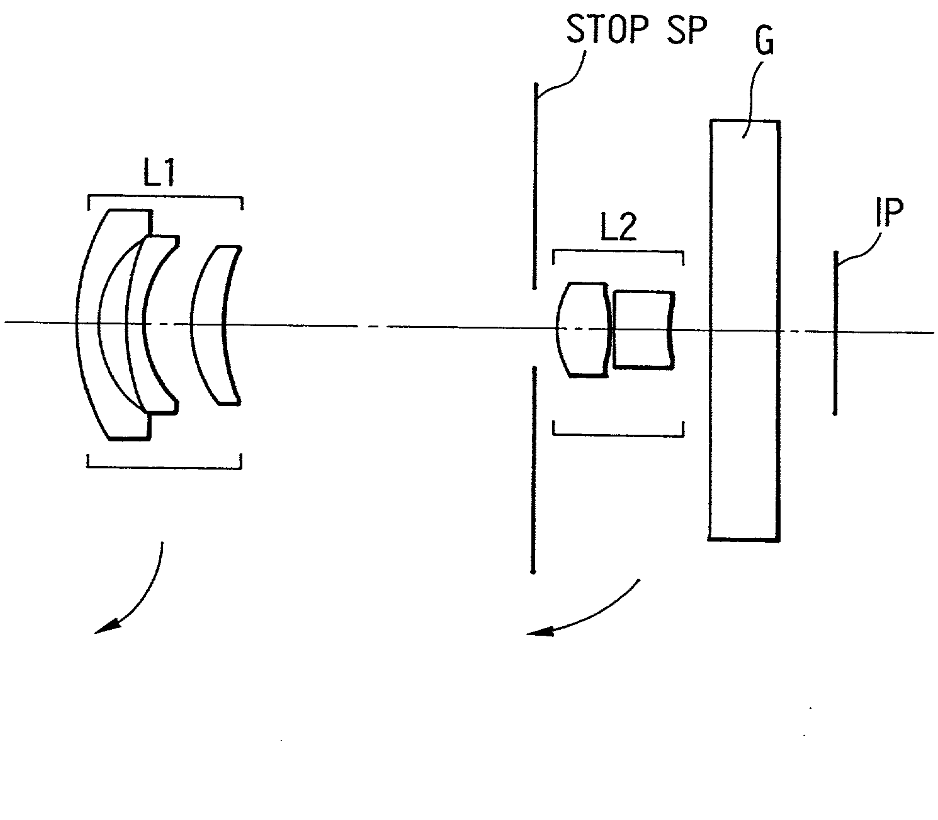


FIG. 3

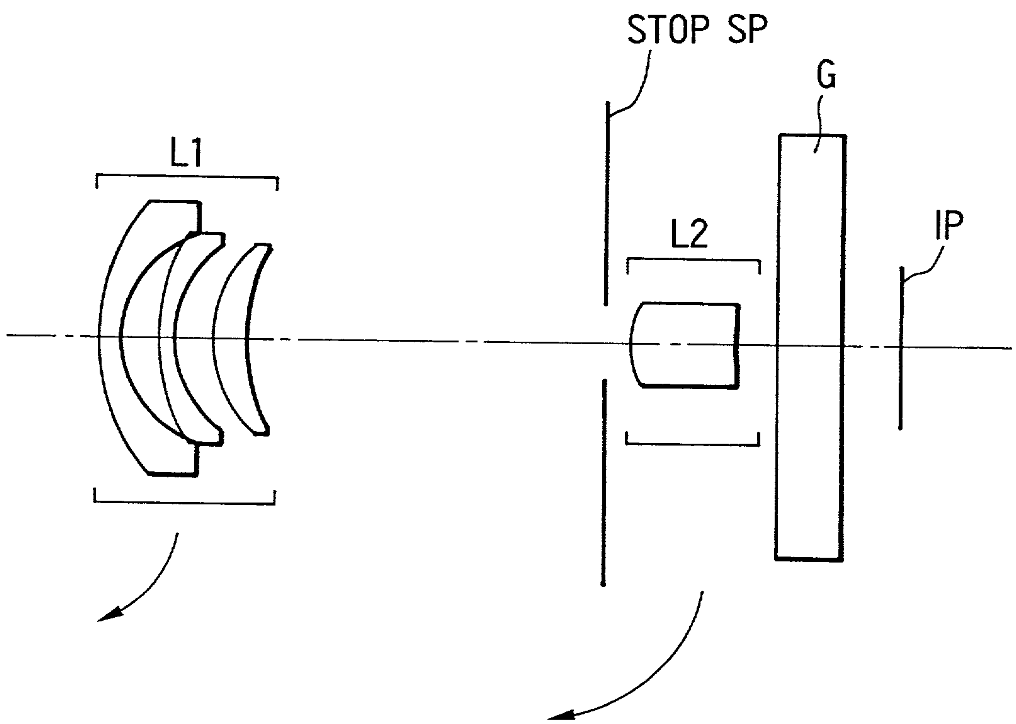


FIG. 4

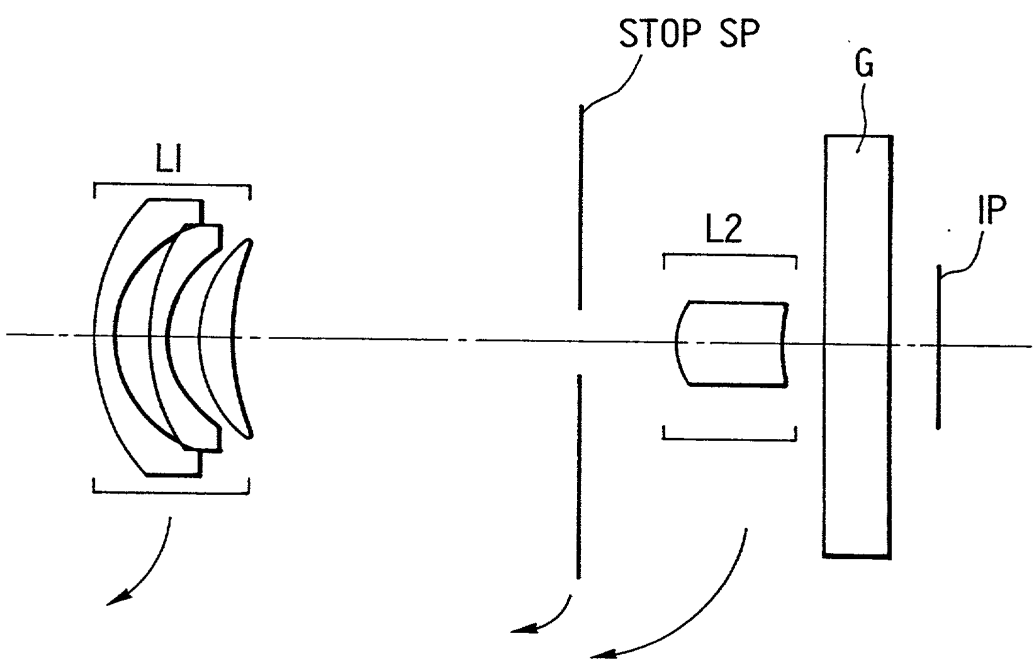


FIG.5

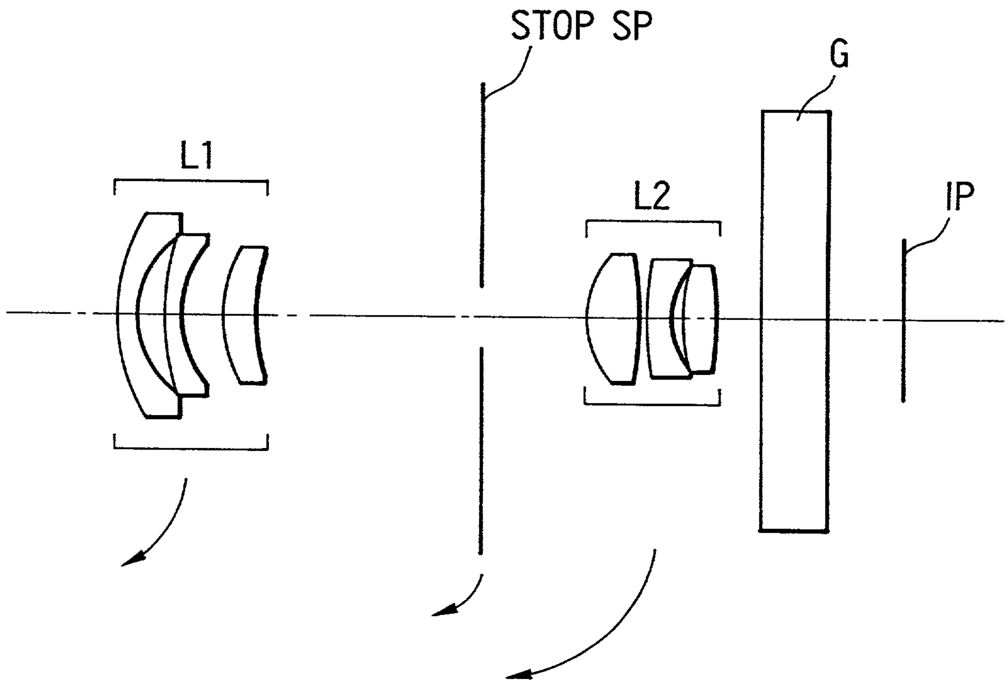


FIG.6

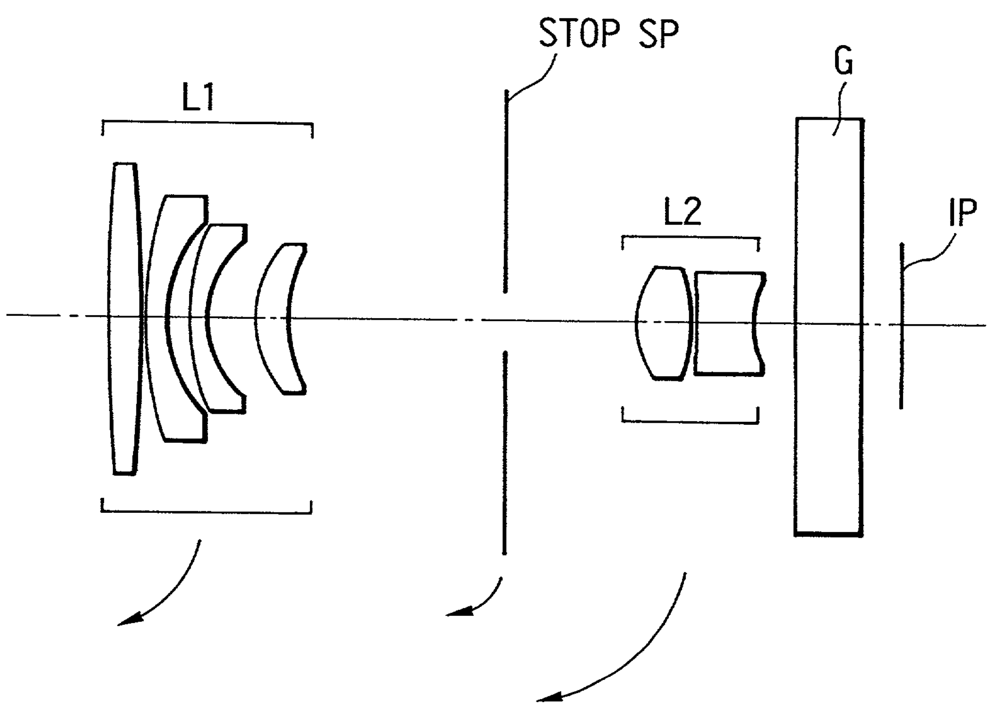


FIG.7

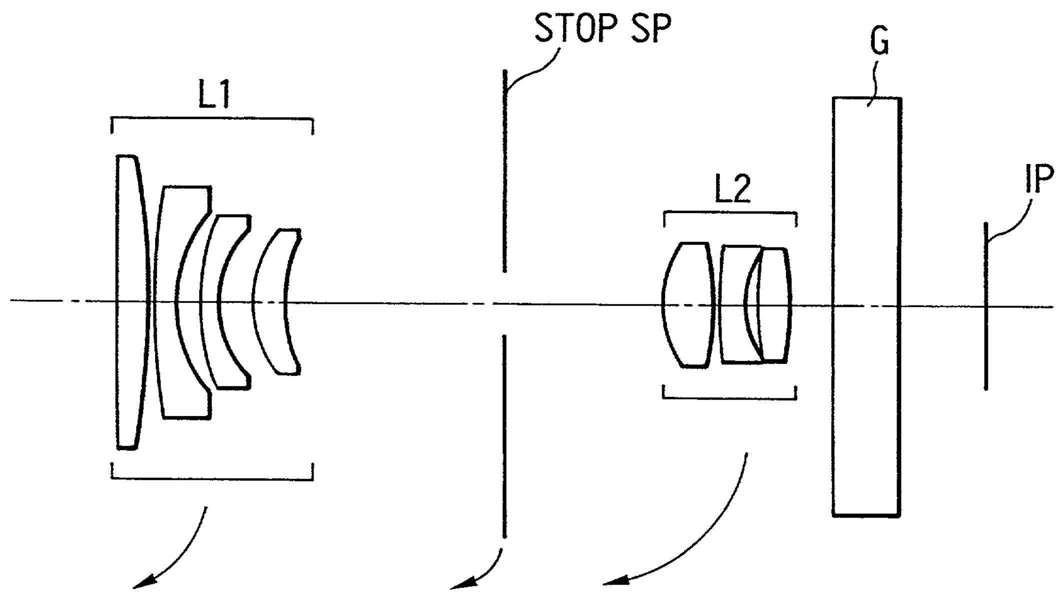


FIG.8

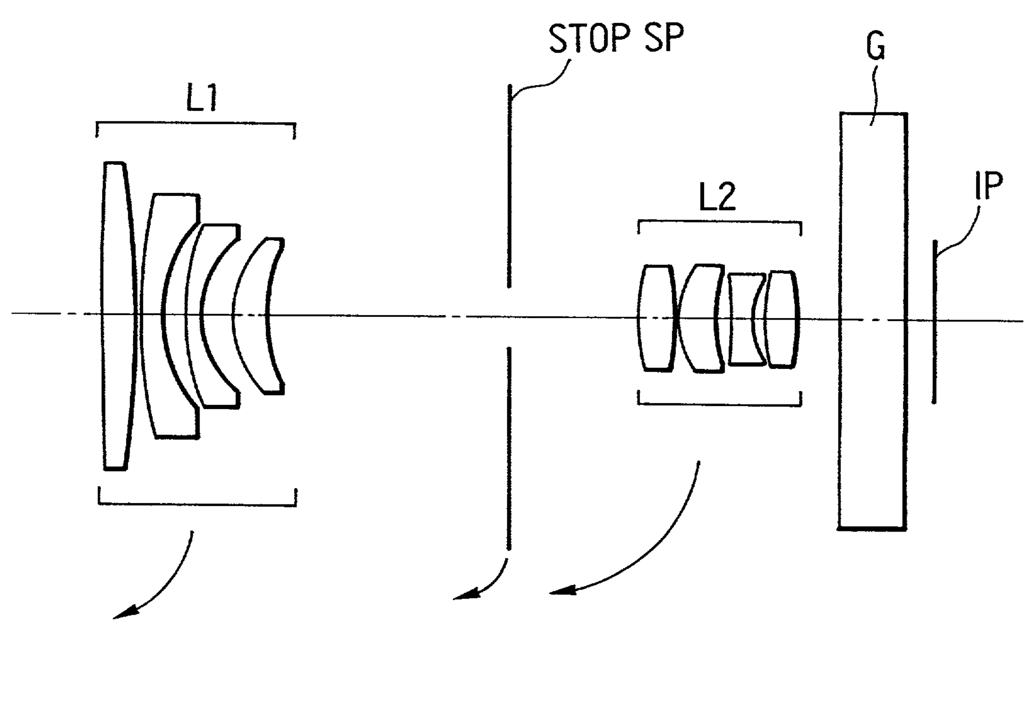


FIG. 9

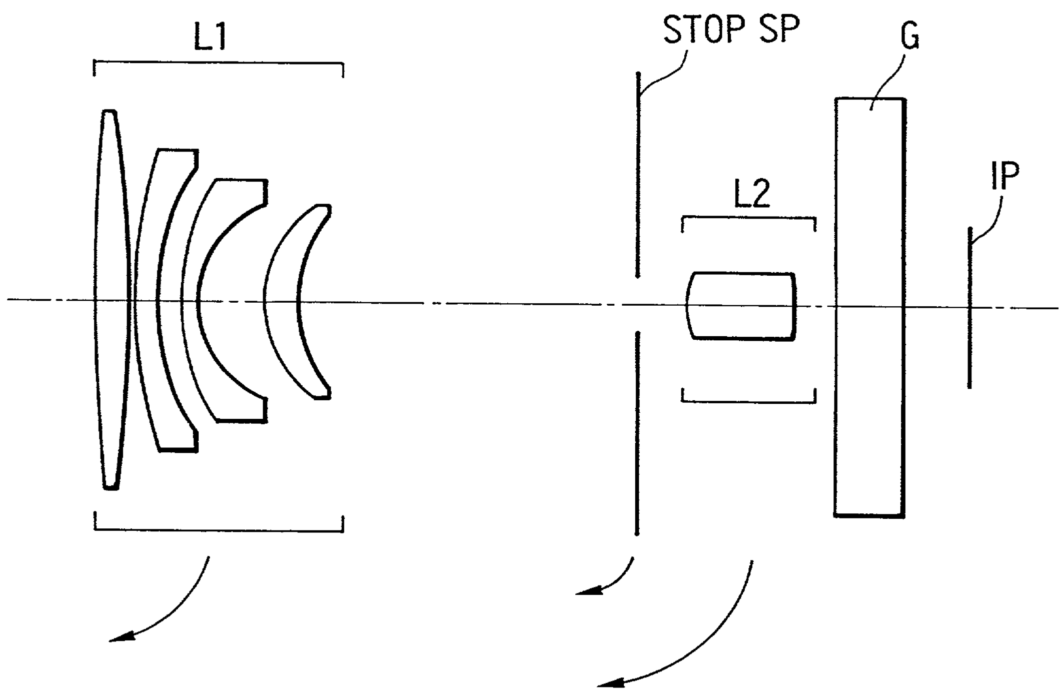
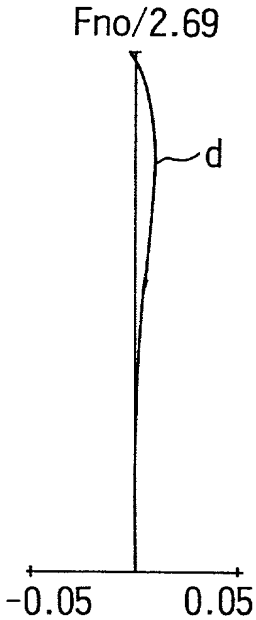
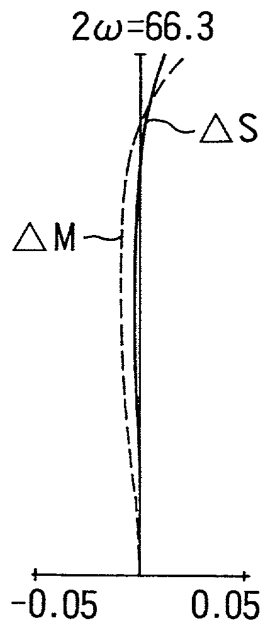


FIG. 10A



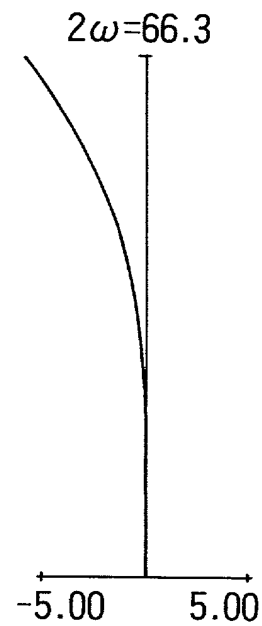
SPHERICAL ABERRATION

FIG. 10B



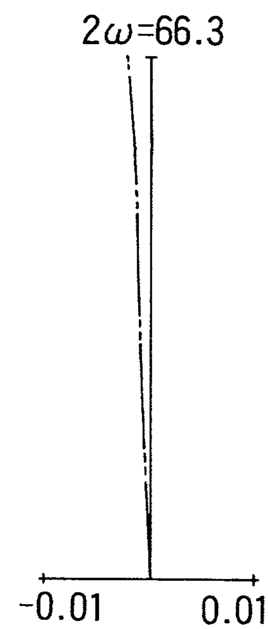
ASTIGMATISM

FIG. 10C



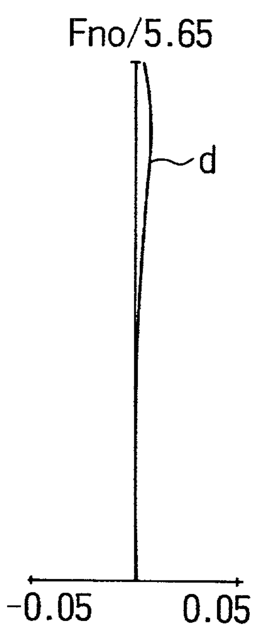
DISTORTION (%)

FIG. 10D



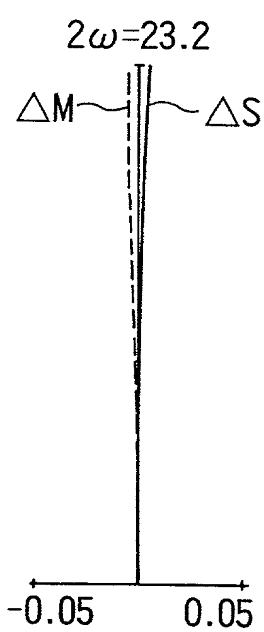
LATERAL CHROMATIC ABERRATION (g-LINE)

FIG. 11A



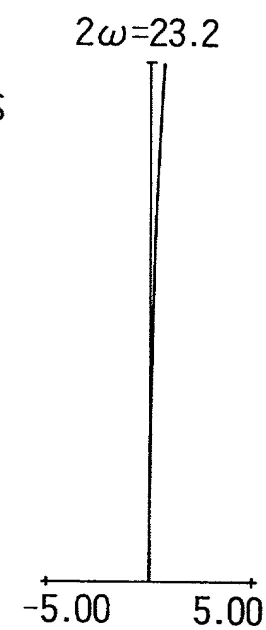
SPHERICAL ABERRATION

FIG. 11B



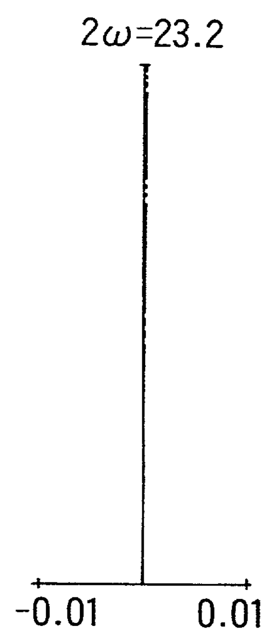
ASTIGMATISM

FIG. 11C



DISTORTION (%)

FIG. 11D



LATERAL CHROMATIC ABERRATION (g-LINE)

FIG. 12A FIG. 12B FIG. 12C FIG. 12D

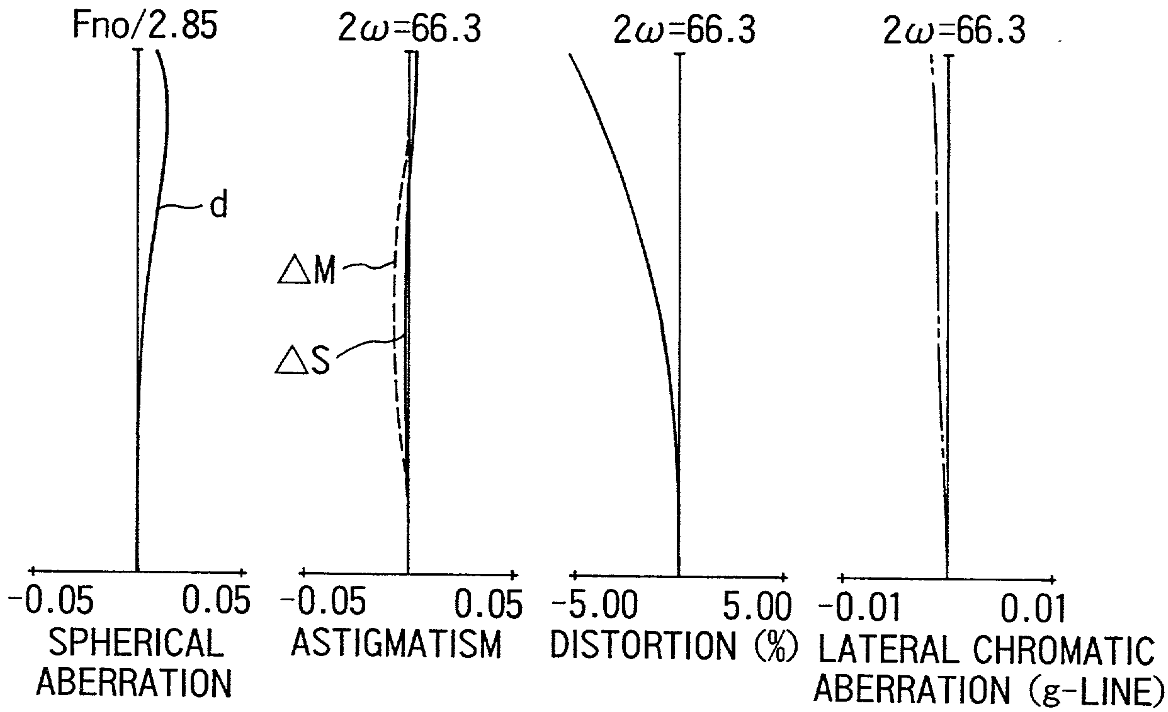


FIG. 13A FIG. 13B FIG. 13C FIG. 13D

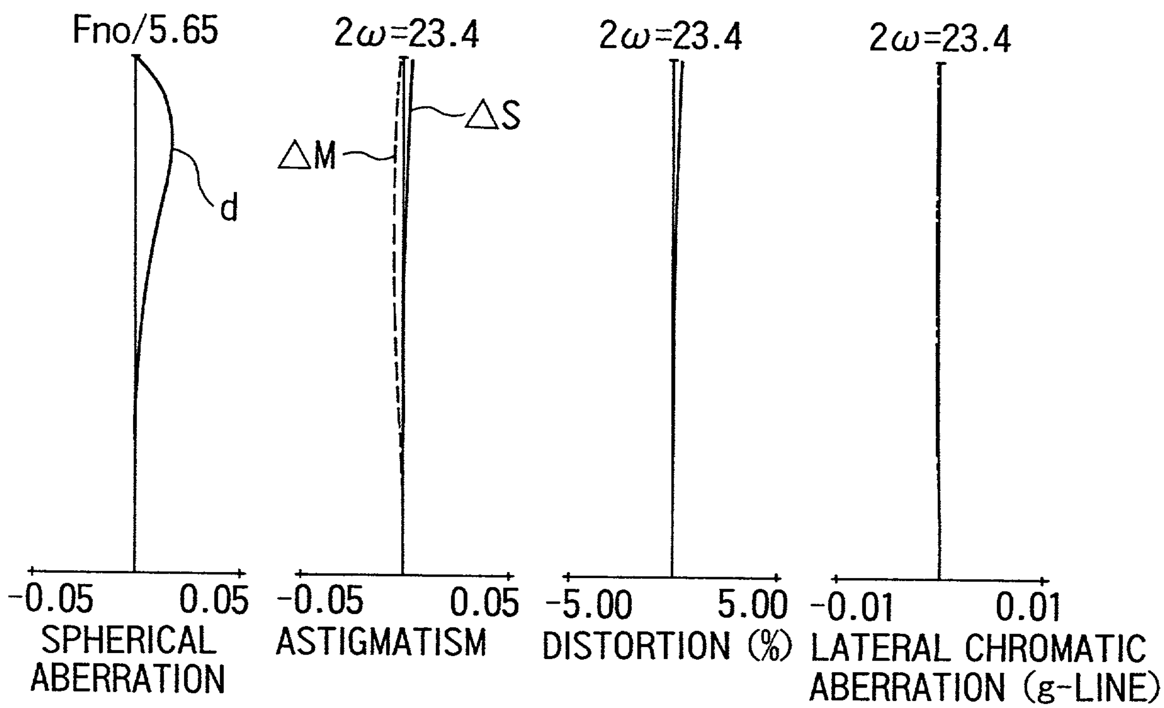


FIG. 14A FIG. 14B FIG. 14C FIG. 14D

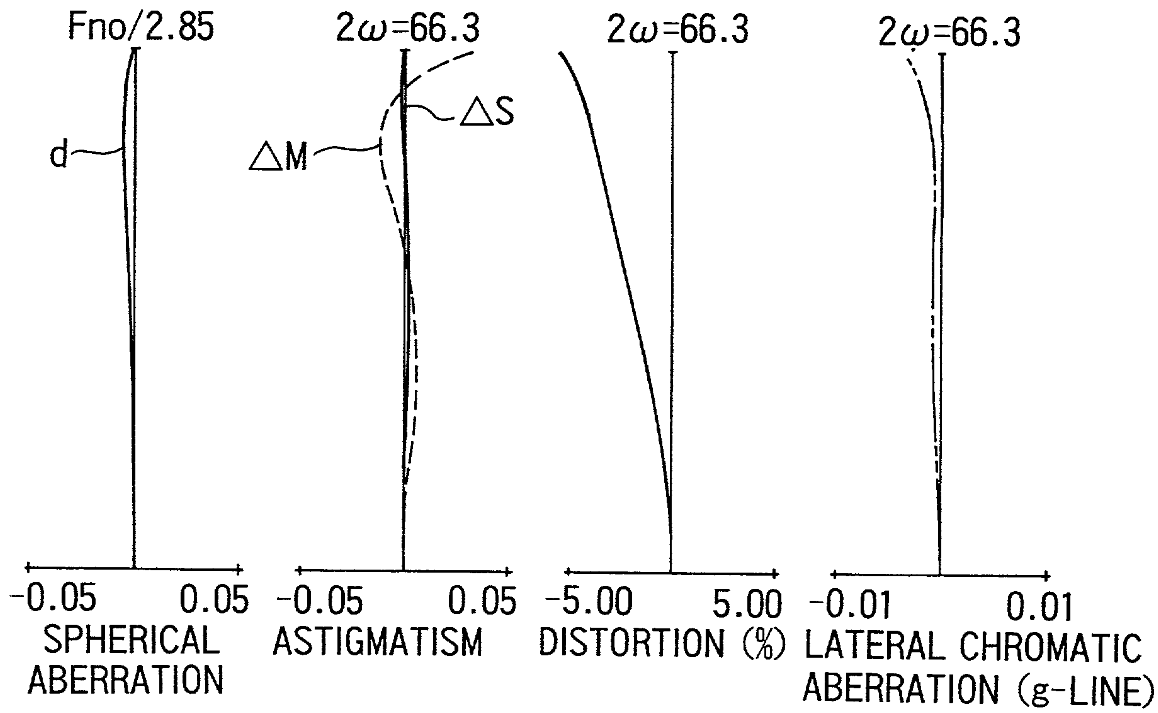


FIG. 15A FIG. 15B FIG. 15C FIG. 15D

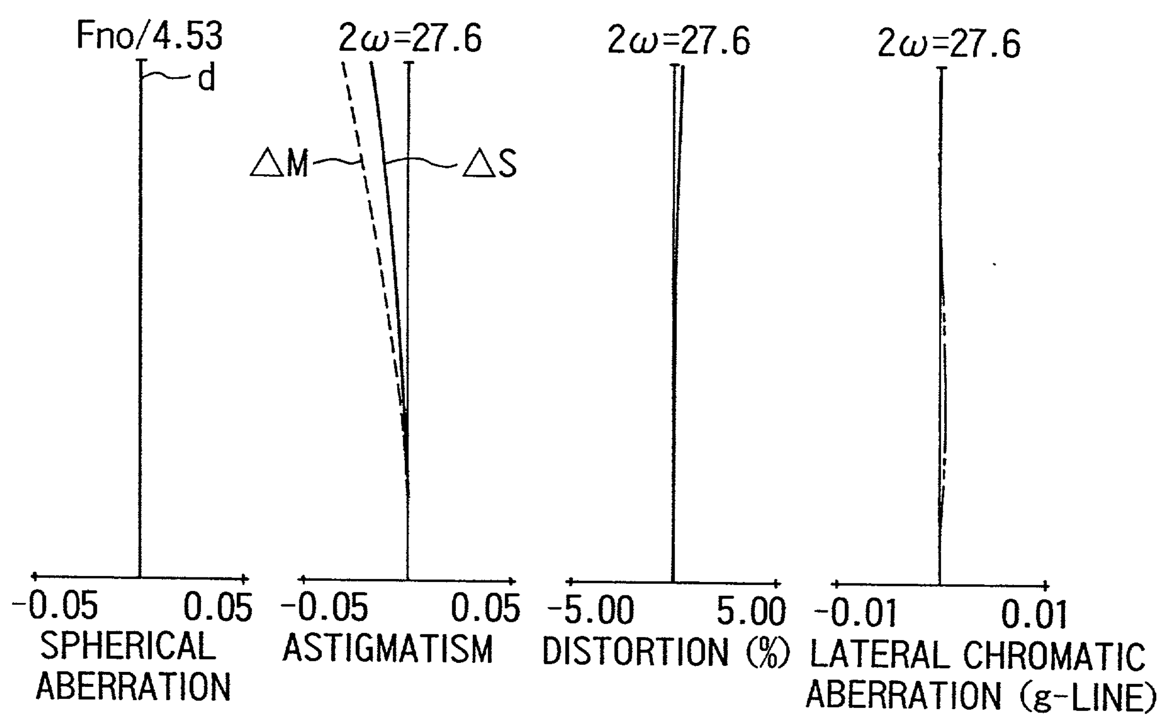


FIG. 16A

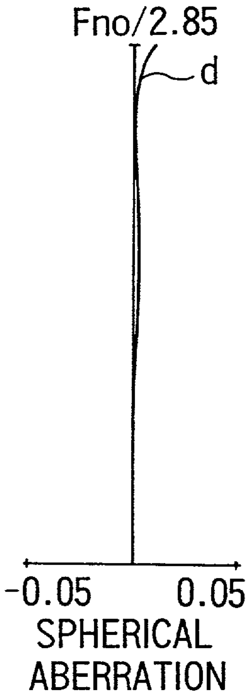


FIG. 16B

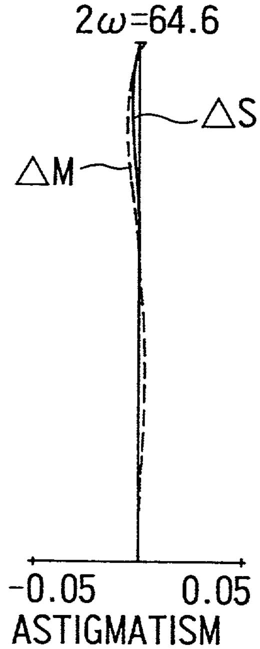


FIG. 16C

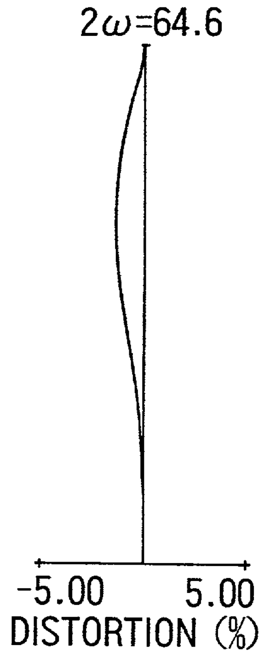


FIG. 16D

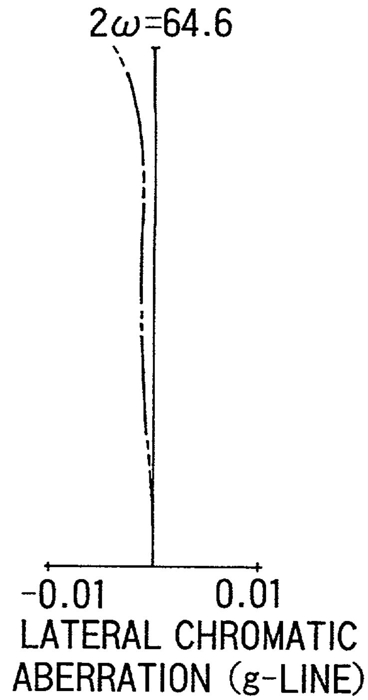


FIG. 17A

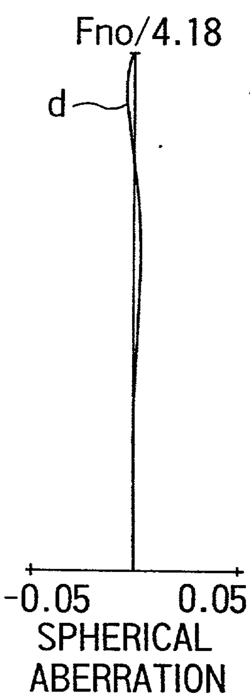


FIG. 17B

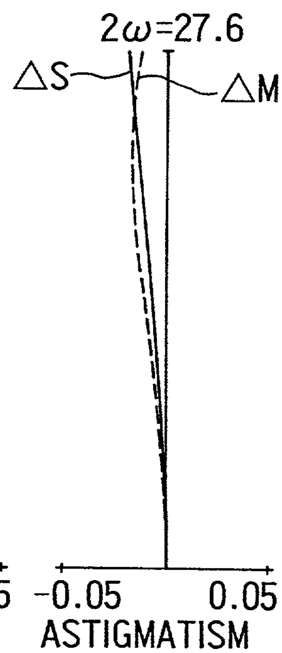


FIG. 17C

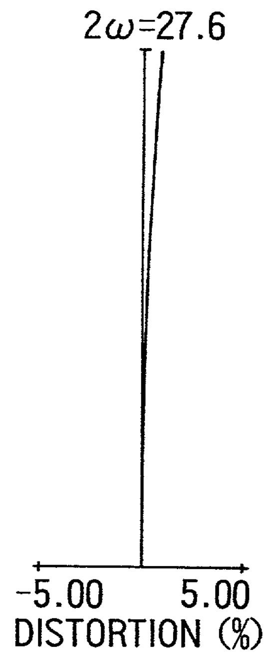


FIG. 17D

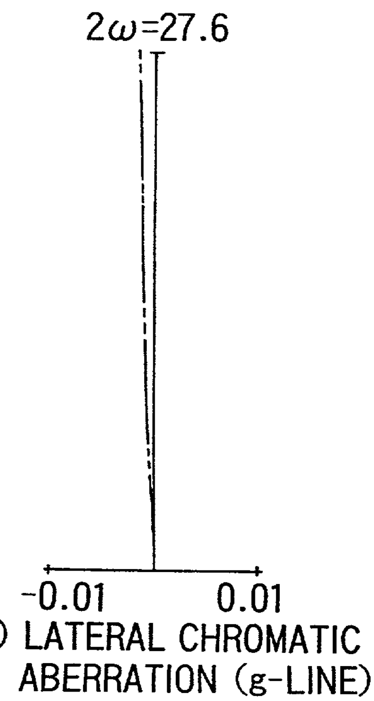


FIG. 18A

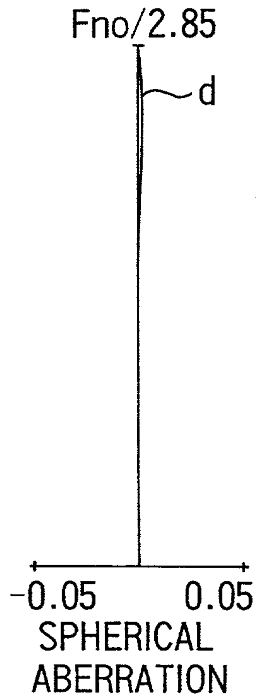


FIG. 18B

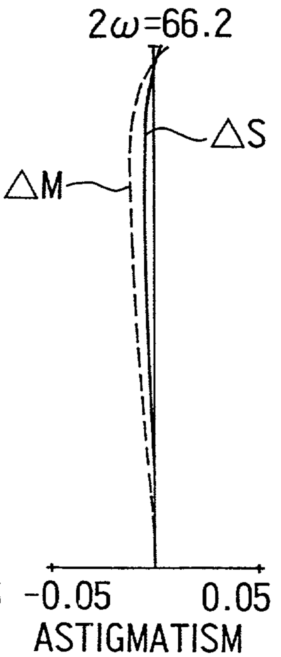


FIG. 18C

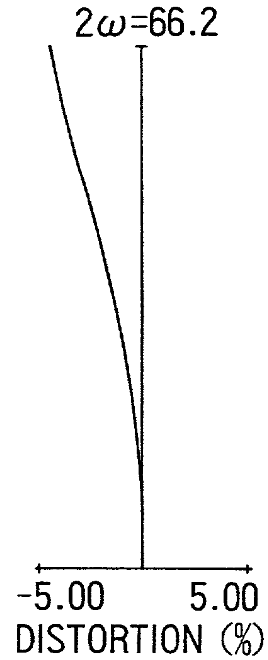


FIG. 18D

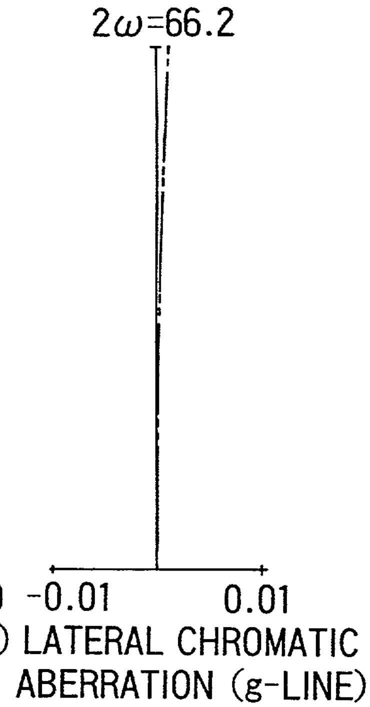


FIG. 19A

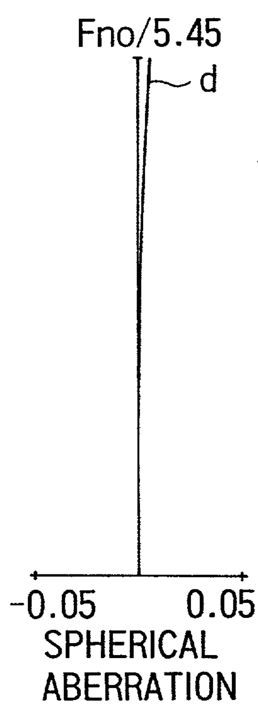


FIG. 19B

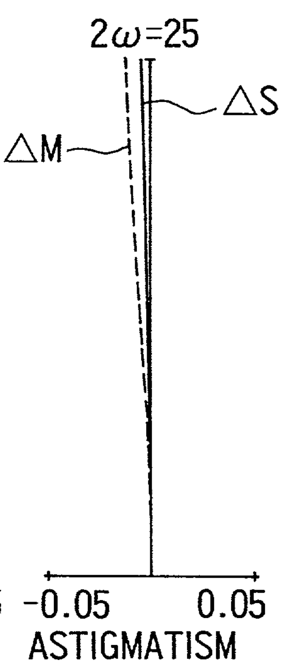


FIG. 19C

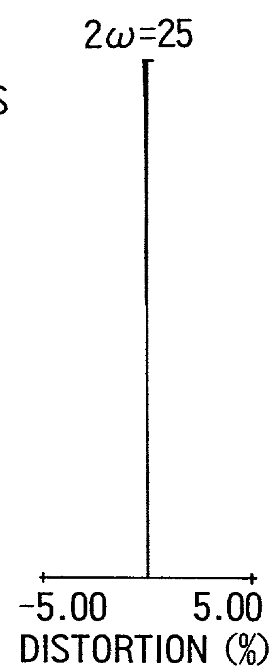


FIG. 19D

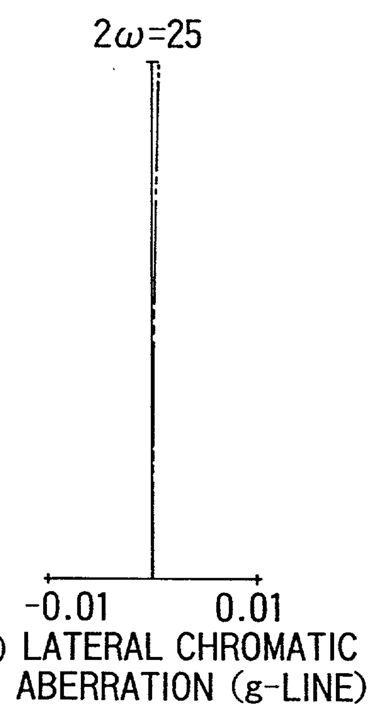


FIG. 20A

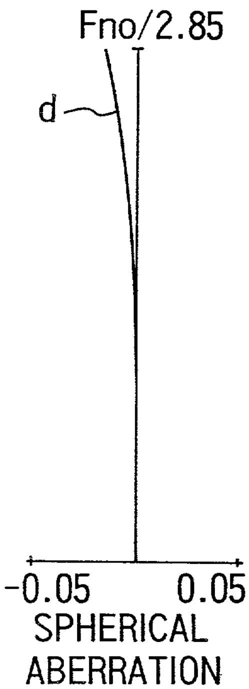


FIG. 20B

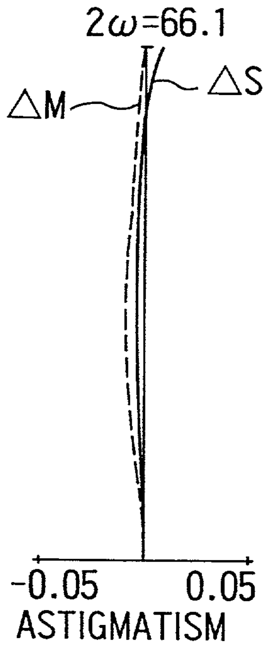


FIG. 20C

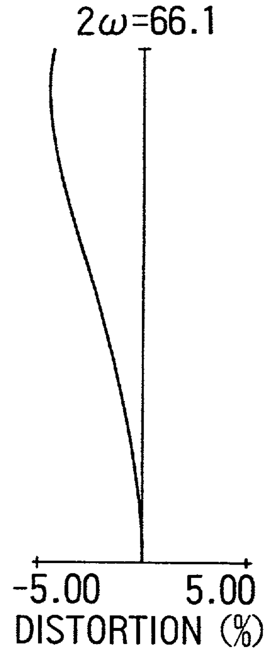


FIG. 20D

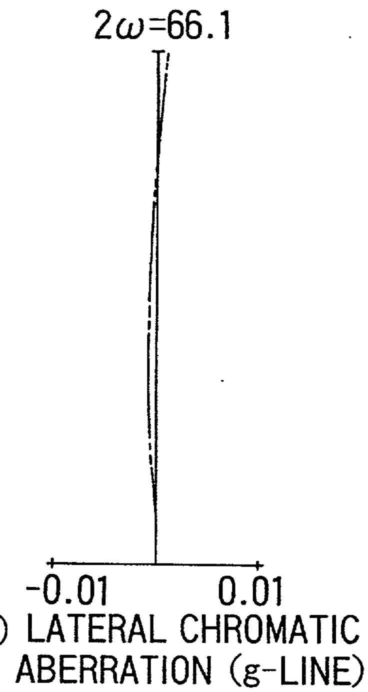


FIG. 21A

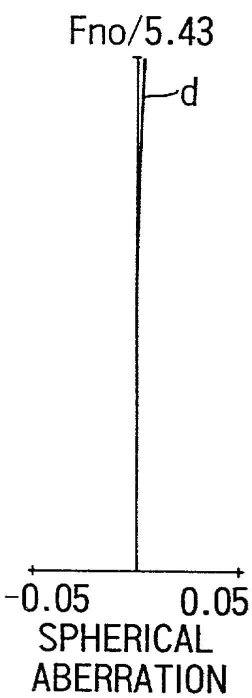


FIG. 21B

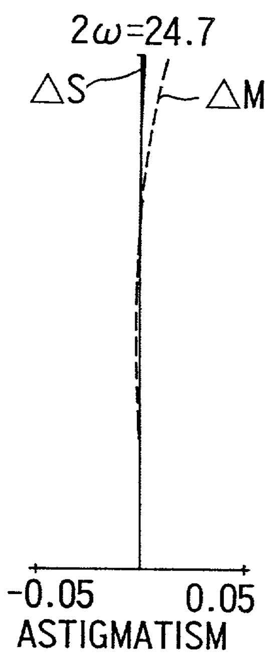


FIG. 21C

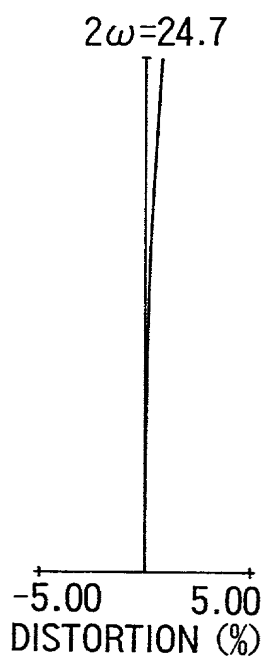


FIG. 21D

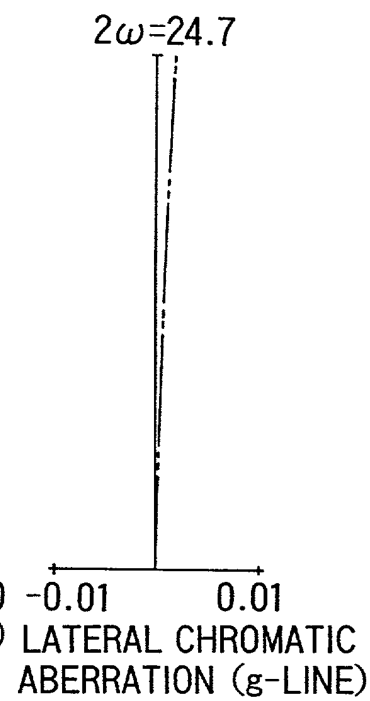


FIG. 24A FIG. 24B FIG. 24C FIG. 24D

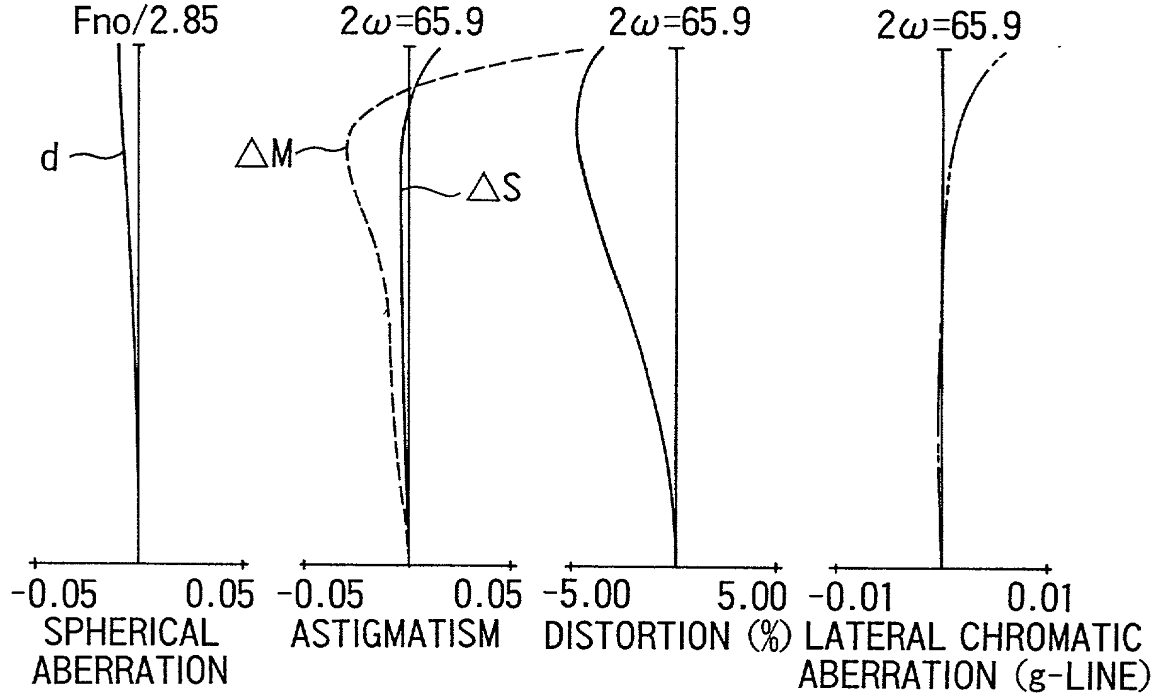


FIG. 25A FIG. 25B FIG. 25C FIG. 25D

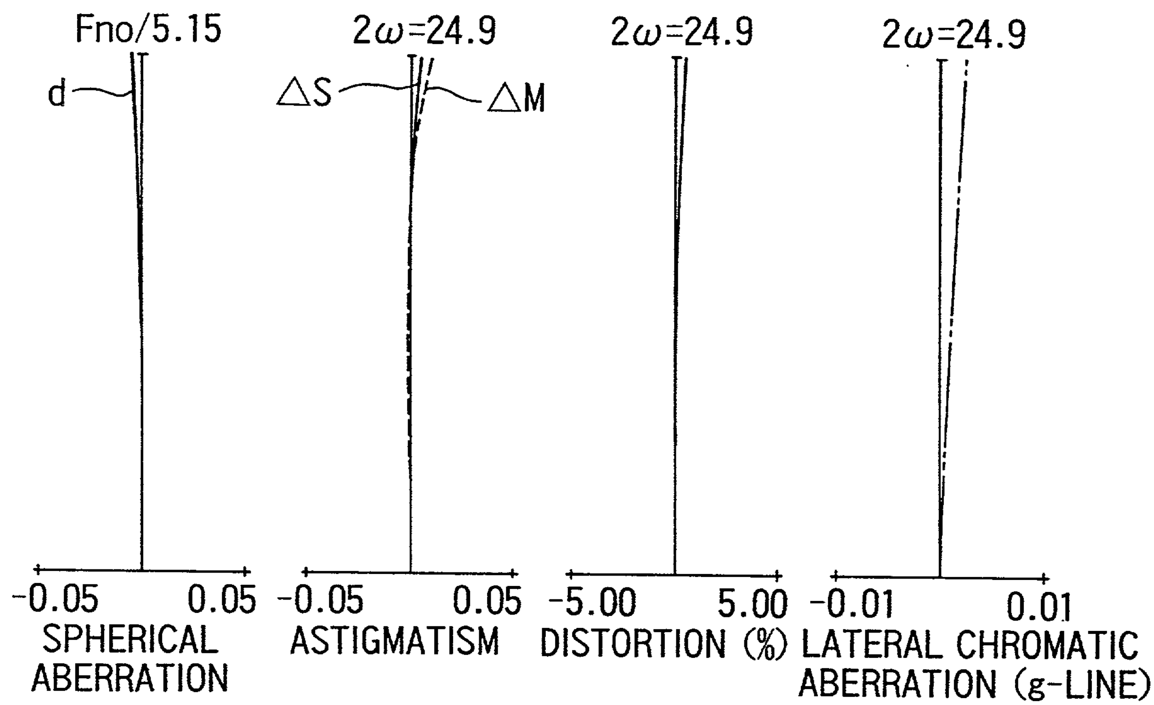


FIG. 26A

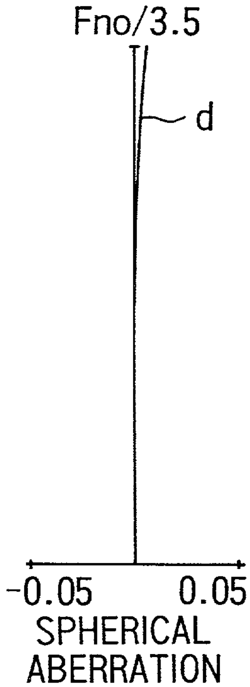


FIG. 26B

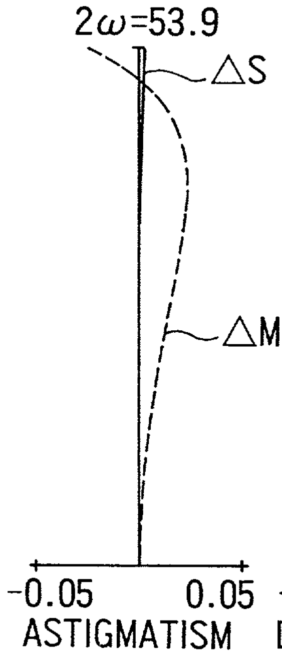


FIG. 26C

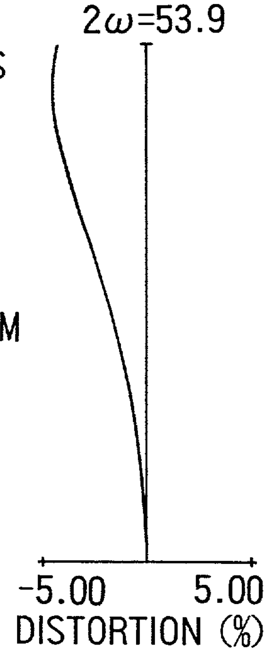


FIG. 26D

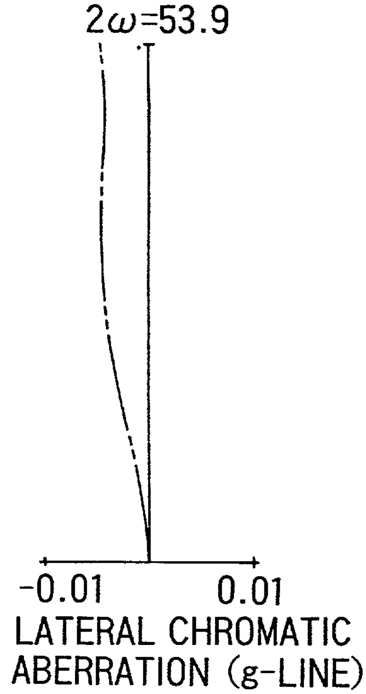


FIG. 27A

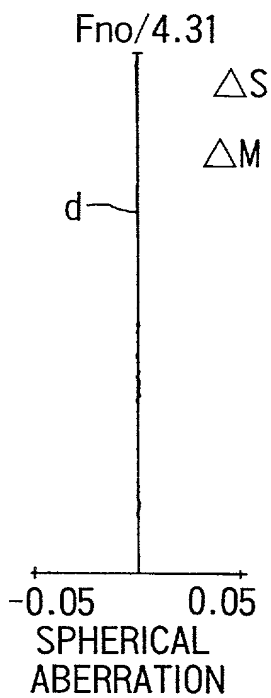


FIG. 27B

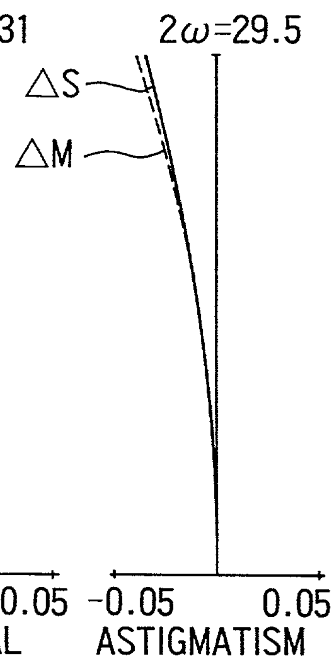


FIG. 27C

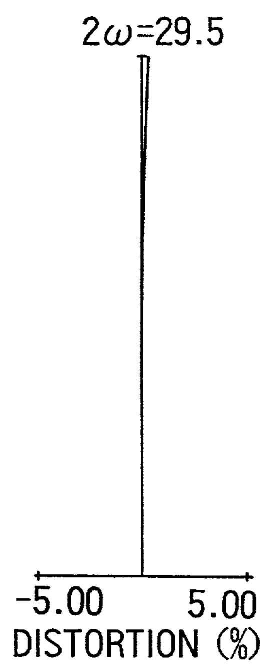


FIG. 27D

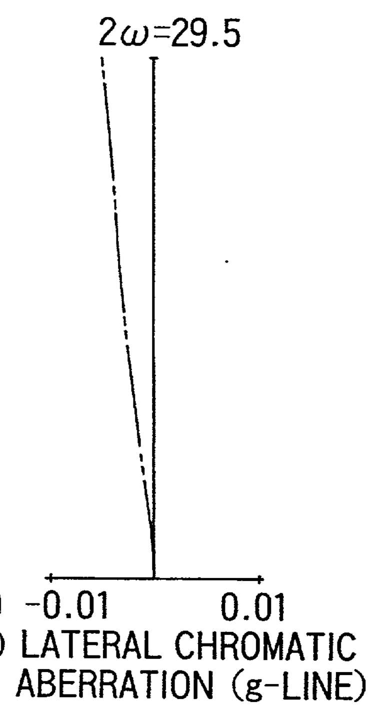


FIG. 28A

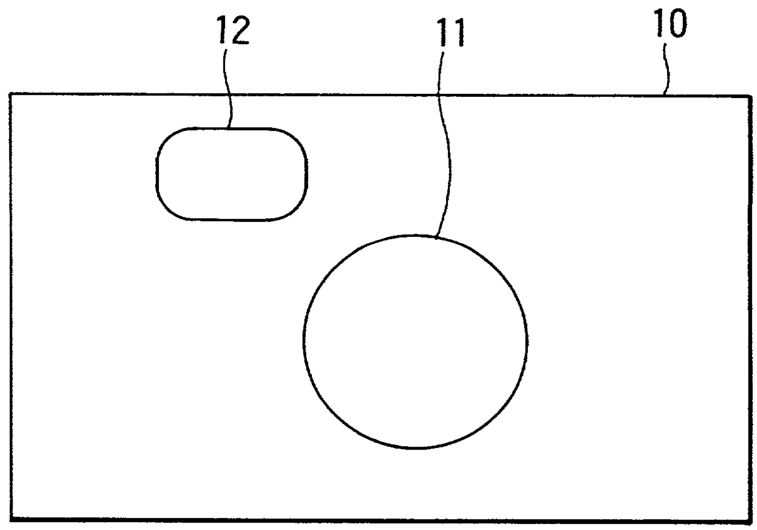
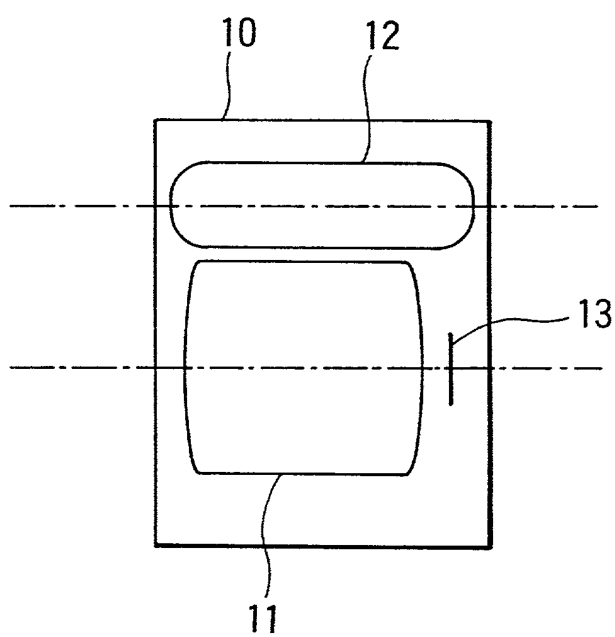


FIG. 28B



CFT4339US

COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION
(Page 1)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled ZOOM LENS AND PHOTOGRAPHING APPARATUS HAVING THE SAME,

the specification of which [ ] is attached hereto [X] was filed on February 12, 1999 as United States Application No. or PCT International Application No. 09/248,979 and was amended on ____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or §365(b), of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT international application which designates at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT international application having a filing date before that of the application on which priority is claimed:

Country	Application No.	Filed (Day/Mo./Yr.)	(Yes/No) Priority Claimed
Japan	Hei 10-054434	19/2/1998	Yes
Japan	Hei 11-011288	20/1/1999	Yes

I hereby appoint the practitioners associated with the firm and Customer Number provided below to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith, and direct that all correspondence be addressed to the address associated with that Customer Number:

FITZPATRICK, CELLA, HARPER & SCINTO
Customer Number: 05514

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Full Name of Second Joint Inventor, if any ____

Second Inventor's signature ____

Date ____ Citizen/Subject of ____

Residence ____

Post Office Address ____